Chase Mill
Winchester Road
Bishop's Waltham
Hampshire
SO32 1AH
United Kingdom

Tel: +44 1489 893 323
Fax: +44 1489 891 851

Fish Guidance Systems Ltd

Monsieur Valério Zuodar
Président
Federation Genevoise Des Societes De Peche (F.G.S.P.)
Case Postale 312
1211 Geneva 25
Switzerland

31 April 1997

Our Reference DRL/870L101

Dear Mr Zuodar,

River Rhône Verbois Dam Fish Herding Project

Further to our letter of 28 April 1997, please find enclosed a copy of the PrISM noise modelling report prepared by Subacoustech Ltd.

As indicated in my fax of the 28th, the report indicates the system specified in our original proposal reference DRL/870P0101 will provide an adequate sound field for the herding process. However, due to the need for a technician to be on site for an addition day we have had to increase the cost slightly, and the revised quotation faxed on 28 April is enclosed.

I trust we have provided all the information you require and look forward to proceeding with this project.

Yours sincerely

David Lambert.

Dr D R Lambert
General Manager

Chase Mill
Winchester Road
Bishop's Waltham
Hampshire
SO32 1AH
United Kingdom

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Fax: +44 1489 891 851

Fish Guidance Systems Ltd

Cost of Hiring a SPA Fish Deflection System
River Rhone, Geneva, Switzerland

Quotation No. 870Q0201

The acoustic system required will comprise:

Qty.	Description
2 off	FGS Model 1-08 Signal Control Units
4 off	FGS Model 400 Amplifier/Monitors
8 off	FGS 30-600 Sound Projectors
2 off	Underwater cable harnesses
2 off	Environmental housings for control equipment
2 off	Mild steel sound projector frames

Hire Charge for System, including carriage to Geneva **£2,675.00**

Since two sound projector frames will be fabricated for this specific installation, these will need to be purchased in addition to the hire charge for the acoustic system.

There will also be the cost for the PrISM modelling to confirm the system configuration, and the cost of an FGS engineer and technician to assemble and run the system during herding the fish, and the technician to maintain the system during drain-down.

The additional costs will be:

1.	PrISM modelling	£1,000.00
2.	Installation, testing and maintenance of system by FGS engineers during drain-down of system (Cost to include all travel and subsistence)	£5,075.00
3.	Mild steel sound projector frames	£725.00

Additional Costs to Hire Charge **£6,800.00**

Total cost of PrISM modelling, hiring acoustic system and purchasing frames, to include all time fees and expenses **£9,475.00**

Signed...D R Lambert...28 April 1997

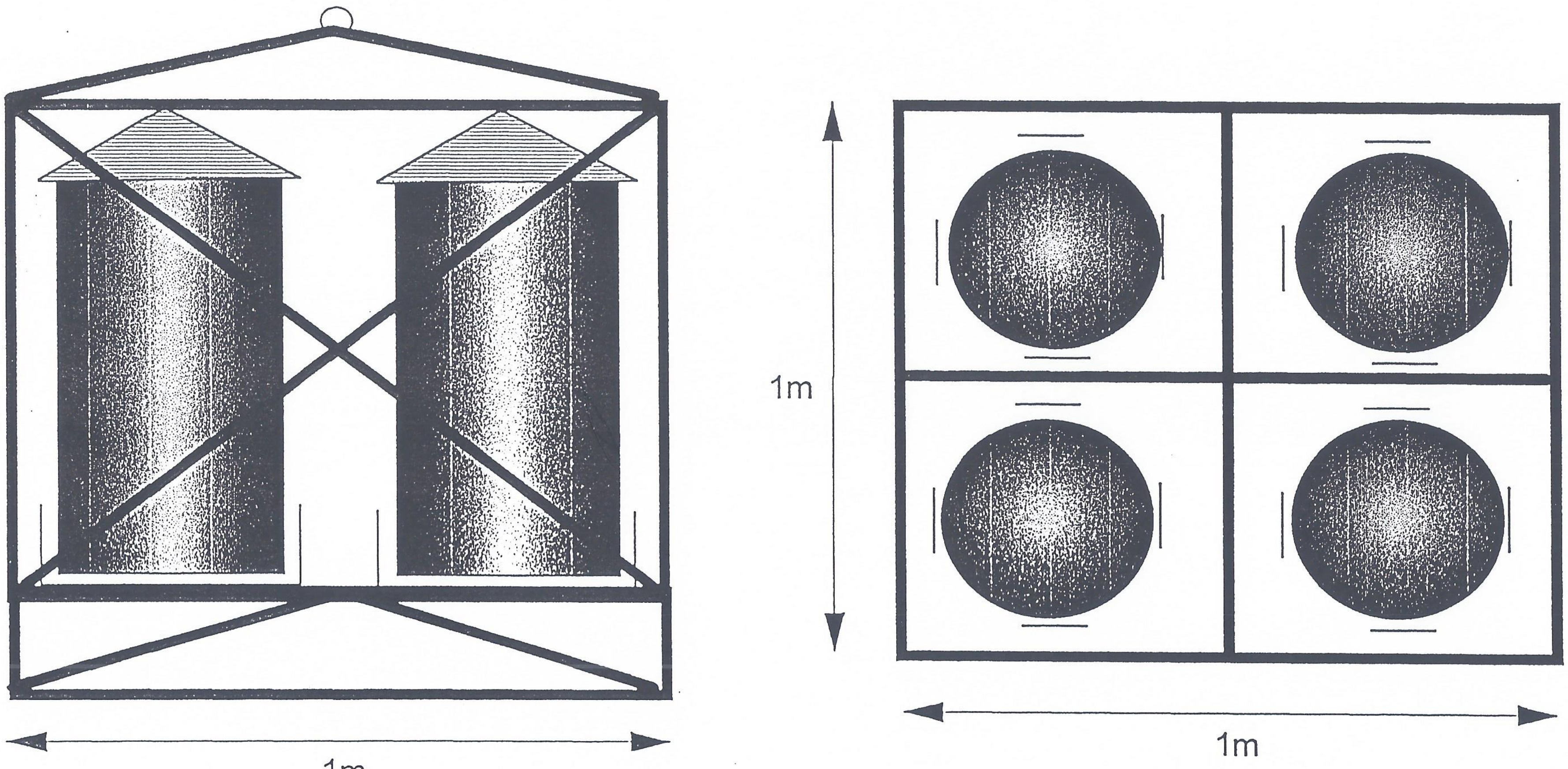
D R Lambert
General Manager

Fish Guidance Systems Ltd
Chase Mill
Winchester Road
Bishops Waltham
SO32 1AH
Tel:01489-893323
Fax:01489-891851

River Rhone Verbois Dam: Fish Herding Project
Project No. 870

Figure 1: Sketch of Sound Projector Frame with 4 Model 30-600 Sound Projectors

Note frames made from 50 mm mild steel angle, painted.



Elevation

Plan

Chase Mill
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SO32 1AH

Tel:01489-893323
Fax:01489-891851

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River Rhone Verbois Dam: Fish Herding Project

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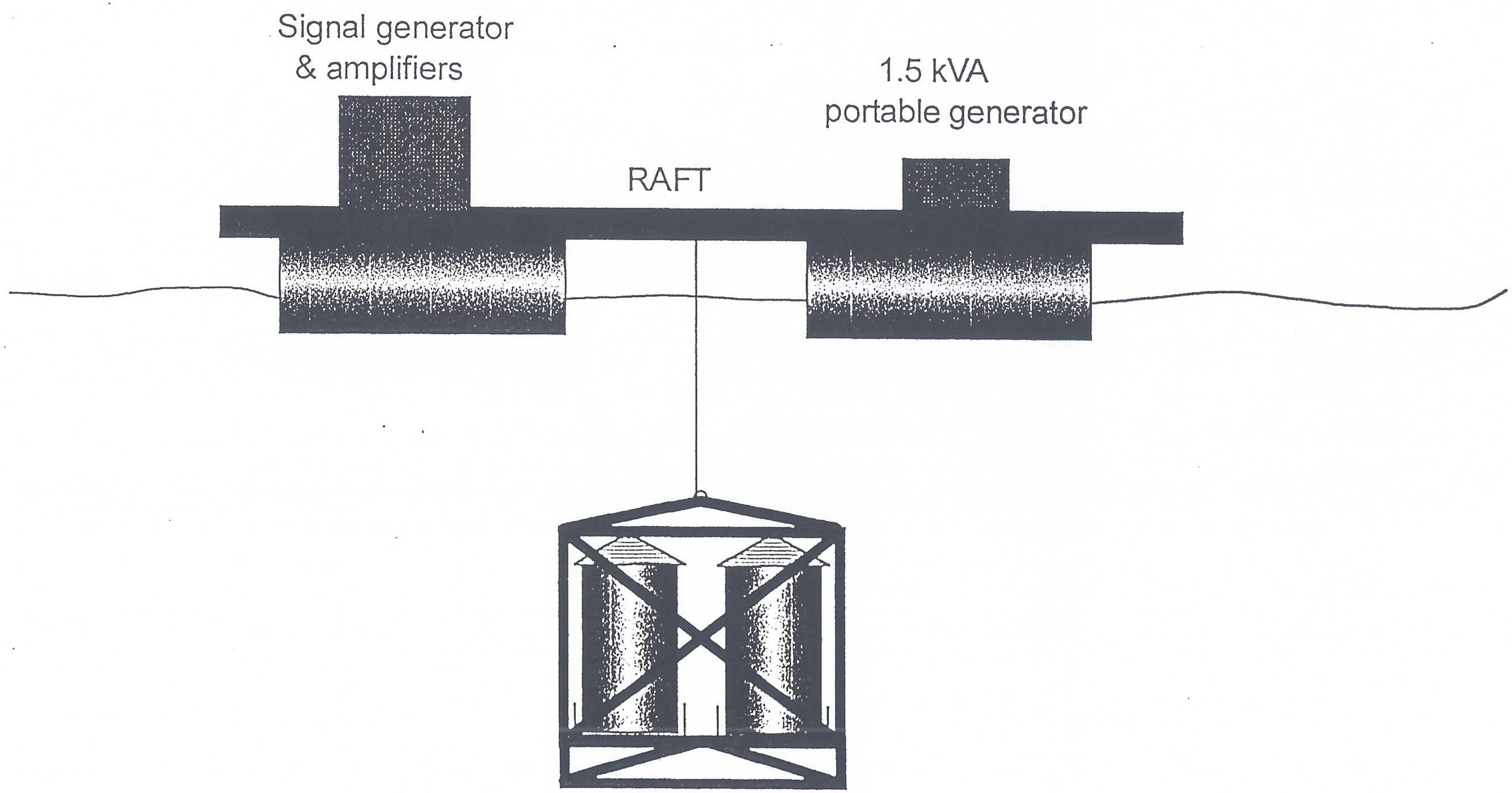
Figure 2: Sketch showing suspension of the sound projector frame from the raft



FGS
Fish Guidance Systems Ltd
Chase Mill
Winchester Road
Bishops Waltham
SO32 1AH
Tel:01489-893323
Fax:01489-891851

River Rhone Verbois Dam:
Fish Herding Project
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Figure 3: Towing Arrangement (section)

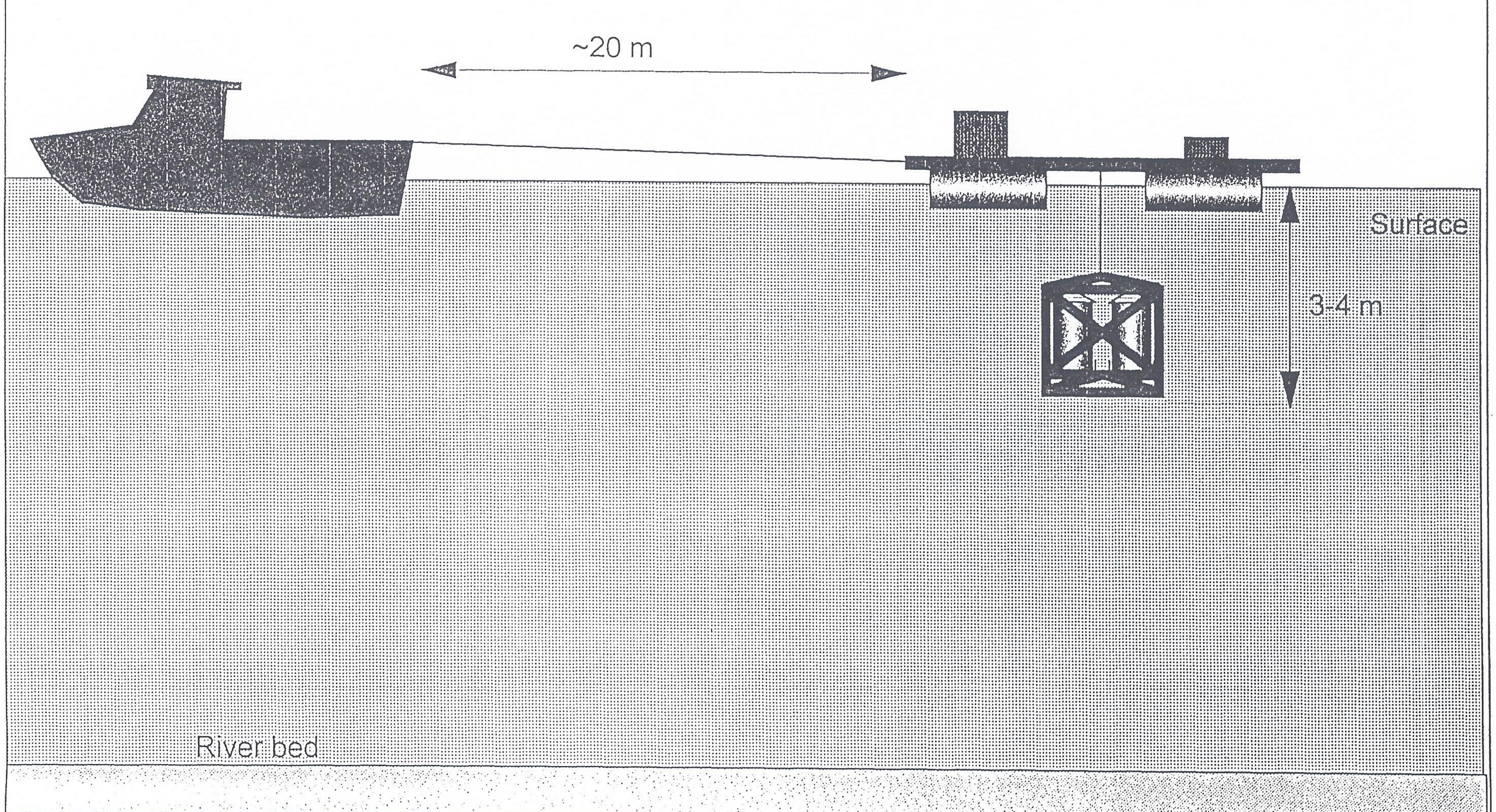

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Figure 4: Towing arrangement (plan view)

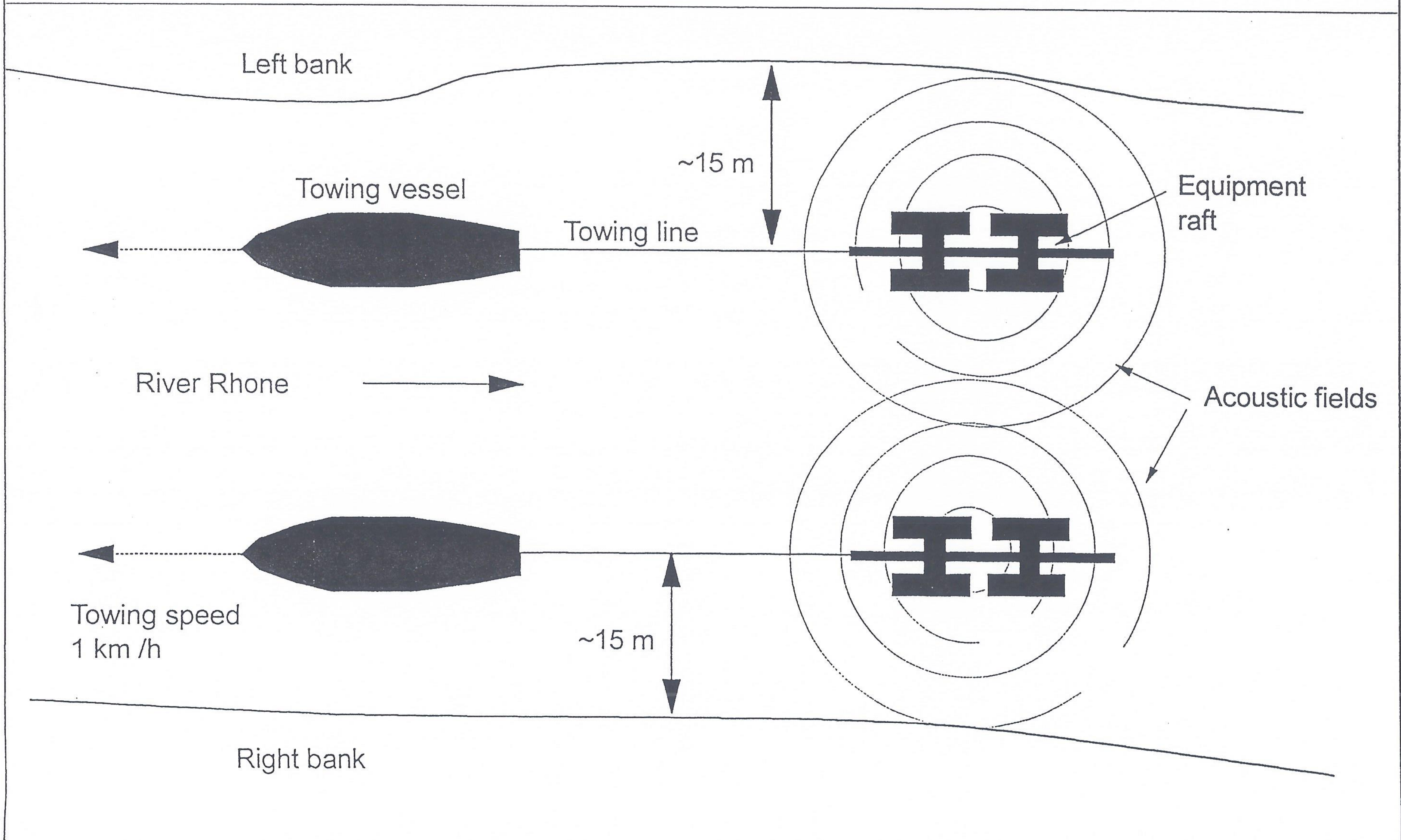

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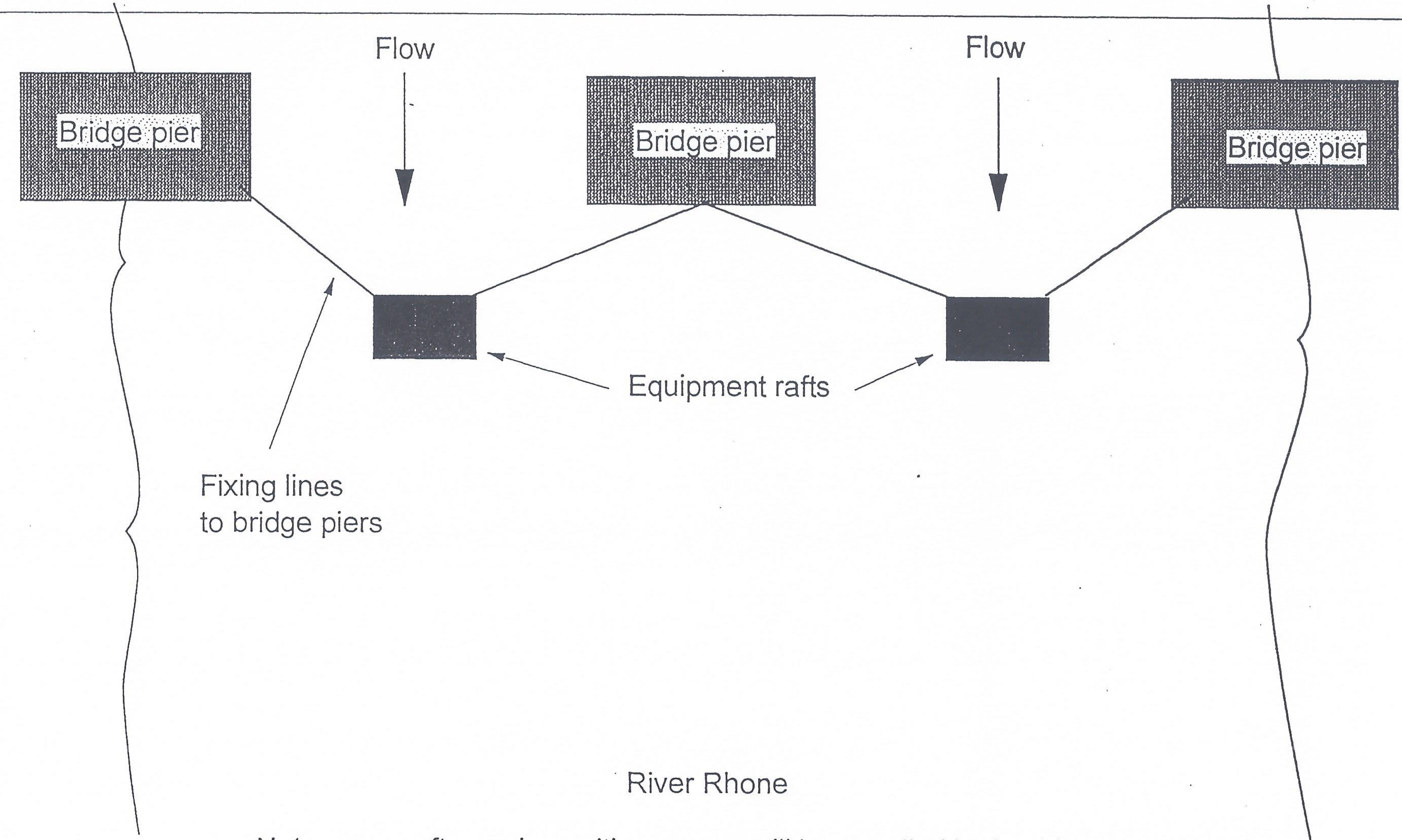
Figure 5: Fixed position of equipment rafts at bridge during drain-down period



Note: once rafts are in position, power will be supplied by land-line from the bridge

FGS

Fish Guidance Systems Ltd has recently moved office.

Consequently, if you would like to discuss any of the FGS products please contact

David Lambert
General Manager

at

Chase Mill
Winchester Road
Bishop's Waltham
Hampshire
SO32 1AH
United Kingdom

Tel: + 44 1489 893 323
Fax: + 44 1489 891 851

Registered in UK No. 2931612 at Alick's Hill House, 126 High St., Billingshurst, Sussex. RH14 9EP

Subacoustech Ltd

Specialist consultants in underwater
and marine related acoustics

Submitted to:

Fish Guidance Systems Limited

Submitted by:

Subacoustech Limited
Chase Mill
Winchester Road
Bishop's Waltham
Hants.
SO32 1AH

Tel. No.: (01489) 891850
Fax No.: (01489) 891851

Acoustical modelling of the proposed fish deflection system for installation in the River Rhône Verbois Dam: Fish Herding Project.

Document Reference: 294R0101.DOC

by

A. Passmore

April 1997

Approved by:..23/4/97

Dr. J. Nedwell, Principal Consultant

Contents. **Page**

1. Introduction.

Fish Guidance Systems Limited (FGS Ltd) tasked Subacoustech Limited to acoustically model a fish deflection system proposed for installation in the River Rhône. for the purpose of herding the indigenous fish upstream during the necessary dredging resulting from the Verbois Dam. This was to be accomplished by using the **Pr**edictive **I**mage **S**ource **M**odel (**PrISM**) developed by Subacoustech.

PrISM was used to produce sound pressure level (SPL) contour maps based upon acoustic energy being introduced into the water by means of collections of sound projectors transmitting a fish deterrent signal. Surveys of sound levels were calculated in three locations, corresponding to position 12, position 6.1, and at the bridge marking the upstream limit of the herding process (figure 1 illustrates these locations). The purpose of the acoustical modelling was to determine whether Sound Projector Arrays (SPAs) would be capable of producing a sound field in which the SPLs exceeded the background noise level by at least 25 dB in a band traversing the river, and the sound fields produced demonstrated a high degree of uniformity i.e. not varying greatly over small distances. If these criteria could be met, it was intended to ascertain the optimum number of projectors, and their spatial location.

It was concluded from the results of the modelling that two 4 unit SPAs (depicted in figure 2), comprising FGS Model 30-600 type projectors, would introduce sufficient sound energy into the river to produce the required signal-to-noise levels. In order to obtain the appropriate coverage across the river channel the SPAs must be driven independently. During the "herding" process i.e. whilst the towing vessels travel from position 12 to the bridge upstream, the SPAs should be deployed as illustrated in figure 3. The centre of the projectors should be at a minimum depth of 3.5 metres, and both SPAs should be perpendicularly removed by 15 metres from the river banks. On arrival at the bridge, the equipment rafts should be positioned as shown in figure 4; the depth location remaining the same.

2. Method.

Sound propagation in shallow water is relatively complicated when compared with that in deep water, since in addition to the wave that travels directly from an acoustic source (a sound projector) to a distant point, there is also a continuum of waves that are generated by the environment in which the propagation occurs.

The sound field created by an acoustic source is further complicated by the fact that efficient reflectors of sound e.g. the water surface, which create a pressure-release boundary with the water, invert acoustic pressure waves at the interface between the media. In other words, waves that have positive pressure as they are incident to the surface leave it as inverted, or negative, waves. Less efficient reflectors of sound form acoustically rigid boundaries with the water, at these interfaces the reflected pressure is unaltered. The occurrence of these phenomena is controlled by the physical properties of media adjoining the water, and to allow for this when modelling shallow water acoustic situations the local topography, bathymetry, and the construct and material of man-made structures must be take into consideration. The acoustic waves may be reflected many times from both the rigid and pressure-release boundaries, leading to a set of waves which may have positive or negative pressure. Reflected waves may interact constructively or destructively with the direct wave yielding a highly complex pressure field in the water.

By taking account of the direct sound contribution from a source and the waves multiply-scattered between surface, seabed, and river banks it is possible to predict the sound pressure level (SPL) that will arise in proximity to the source.

PrISM is utilised in an iterative process. An initial configuration of sound projectors is selected based on empirical acoustical factors and experience. PrISM is run and the field evaluated in terms of its deflection efficiency. It is likely that the first configuration of Sound Projector Array (SPA) will not satisfy all the proposed specifications so modifications are required. Subsequently, this investigative procedure produces sound projector configurations which suit the acoustical situation better than their predecessors, eventually allowing the determination of a fish deterrence system that fulfills the design criteria.

Fish Guidance Systems specified that the deterrence system should be proven in 3 locations along the river. The modelling would be started at position 12, the optimum design of SPAs resulting from this would then be tested at position 6.1, and finally, testing would occur at the static terminal position at the bridge upstream.

For the fish deterrent system proposed for installation and use in the River Rhône, calculations of SPL were performed numerically for differing numbers and arrangements of sound projector. Initially, a frequency of 100 Hz was used as the signal emitted by the sound projectors. This was selected because it represents an intermediary value frequency from the signal intended for transmission. Having opted for a particular configuration for the SPAs, investigations were performed into the effects of varying the transmitted frequency, the depth of the horizontal survey plane, and the vertical location of the SPAs.

The results are presented versus two spatial coordinates in figures 5 to 38 of this report.

3. Results.

All of the graphical results provided within this report illustrate the signal to noise levels calculated by PrISM. Each value represents the difference between the predicted sound pressure level (SPL) and the background noise level. Because of a lack of data describing the latter, a moderate value of 100 dB was assumed. The contour graphs are orientated such that the bound edge of the page indicates the upstream direction. The areal extent modelled is denoted on each figure; as a minimum 40 metres upstream of the SPAs is covered, allowing inspection of the area in which the design criteria were to be met.

Fish Guidance Systems Limited (FGS) stipulated a preference to use the FGS Model 30-600 type sound projectors for this installation. The suggested method of SPA positioning, encouraged the use of independent signal generators for the two separate SPAs. An advantage of this method is the promotion of greater sound field uniformity; this is by virtue of the sound from the two SPAs being incoherent, and hence the signals transmitted from each SPA do not interfere with one another. For this reason, there are two results for each situation examined, one for each of the incoherent SPAs. Conclusions as to the effectiveness of each SPA are made by examining each pair of results.

The first step in the modelling process was to ascertain what number of projectors would be capable of producing sufficiently high sound levels i.e. exceeding the background noise level by 25 dB or more over the designated area. A simple calculation of transmission loss indicated that two Model 30-600 projectors might accomplish this. Position 12 was the first location to be tested, and figures 5 and 6 show the resulting SPLs. There is a high degree of uniformity to the sound fields; the benefit of using incoherent SPAs is apparent, as the unwanted nodal patterns associated with severe interference between sources are not displayed. However, viewing both of these figures, it is possible to see that this number of projectors is inadequate; the mid-channel SPLs are only 15-20 dB above the background noise level. In other words, the sound levels must be increased by about 15 dB in this area. By doubling the number of projectors, the SPLs produced would be increased by 6 dBs. Therefore, by replacing each singular projector with a collection of four the necessary gain in level would be achieved. Figures 7 and 8 illustrate the SPLs produced by two SPAs (each containing 4 Model 30-600 projectors); they exceed background noise levels by 30 dB or more in the target area. The increase in numbers of projectors does not affect the acceptable uniformity of the sound fields displayed by the smaller SPAs.

Having determined the size of the SPA that would introduce sufficient sound energy into the River Rhône at position 12, so generating the necessary SPLs, the next stage in the modelling was to experiment with the placement of the SPAs, and hence determine the optimum positioning. Primarily this was accomplished by modifying the distance between the river banks and SPAs. The overall trends of this examination are typified in figures 9 to 12. The sound fields deteriorate in terms of uniformity when the distance between the SPAs and the banks is either increased or decreased. Additionally, both of these modifications produce a reduction in signal to noise levels. This procedure indicated that the best separation between the SPAs and the river banks was 15 metres.

The variation to the SPLs caused by changing the transmitter frequency and the depth of the survey plane was investigated. Ordinarily, relatively "high" frequencies and sound fields in relatively close proximity to the water surface are likely to produce more variable sound fields, highlighting potential problems resulting from non-uniformity of sound pressure; both of these tendencies were encountered. The sound contour maps predicted for the extremes of the signal to be transmitted are shown in figures 13 to 16. When the frequency is lowered to 50 Hz the field uniformity improves, and the extent of the sound level bands remains largely unaltered. Raising the transmitted frequency to 300 Hz is accompanied by a slight degradation of the sound field uniformity but an advantageous increase in the extent of the 35-40 dB region. The calculations performed by PrISM indicate that the proposed SPAs produce adequate sound fields in the frequency range intended for transmission. Examination of figures 17 to 20 shows the results obtained at a number of survey depths while maintaining the depth position of the SPAs. Movement of the survey plane towards the water surface produces an increase in the variation of the SPLs with horizontal movement, and there is little or no effect when the survey plane is lowered towards the river bed. Even though the uniformity of the sound field worsens towards the water surface, it is still acceptable.

Having previously established the best horizontal positioning for the SPAs, an investigation into the optimum vertical siting for the SPAs was performed. Figures 21 to 24 demonstrate the findings of this exploratory work. Raising the SPAs closer to the water surface causes a slight reduction in sound field uniformity, a reduction in the extent of the 30-35 dB region perpendicular to the river banks is also evident. Lowering the SPAs produces very little effect. This indicates that the SPAs should be positioned at a minimum of 3.5 metres depth below the water surface. Inspection of the free-issue river profile information supplied by FGS shows that at 15 metres from the river banks 3.5 metres depth is achievable.

The SPAs defined during this procedure were then tested at position 6.1. Figures 25 to 30 represent a sample of the results obtained. The SPAs meet the required specifications pertaining to SPLs and sound field uniformity; the best results were obtained with the SPAs located at a depth of 5.5 metres. The SPAs would still meet the criteria if the transmitted frequency were varied between the signal limits, and the sound fields produced at depths other than those presented were also acceptable.

Finally, the sound levels generated when the SPAs were positioned between the bridge piers were calculated. Figures 31 to 38 represent a selection of the results, illustrating sound fields produced at different depths and variations to SPLs caused by changing the horizontal positioning of the SPAs. On all of the diagrams, the location of the bridge piers is marked by the square areas having a signal to noise level of 0 dB. Figures 33 to 36 show that the sound fields produced at horizontal depths of 3.5 metres and 5.5 metres adequately meet the design requirements. However, the results obtained at 1.5 metres (figures 31 and 32) show areas immediately adjacent to the bridge piers where the SPL drops to within 20 dB of the background noise level. To increase these levels, the distance from the SPAs to the river banks was changed. The optimum result in the 1.5 metre survey depth, produced by the configuration depicted in figure 4, is shown in figures 37 and 38; these SPAs meet the design specification.

4. Conclusions.

In summary:-

1. The PrISM modelling performed for position 12, position 6.1, and the bridge upstream of the Verbois Dam indicate that SPAs are capable of producing signal to noise levels in excess of 25 dB and sound pressure fields displaying high degrees of uniformity.

2. To produce the appropriate sound pressure levels (SPLs), traversing the River Rhône, it will be necessary to utilise two independently driven SPAs, comprising 4 FGS Model 30-600 sound projectors.

3. During the “herding” process these SPAs will be suspended at a minimum depth of 3.5 metres below equipment rafts, and maintained at distances of 15 metres from the river banks.

4. At the final bridge location, the SPAs should be deployed approximately 19 metres downstream of the bridge piers, and 25 metres from the river banks (as shown in figure 4).

5. Figures.

Figure 1

Map depicting the area over which herding will be carried-out.

Figure 3

Illustration of SPA positioning during herding process.

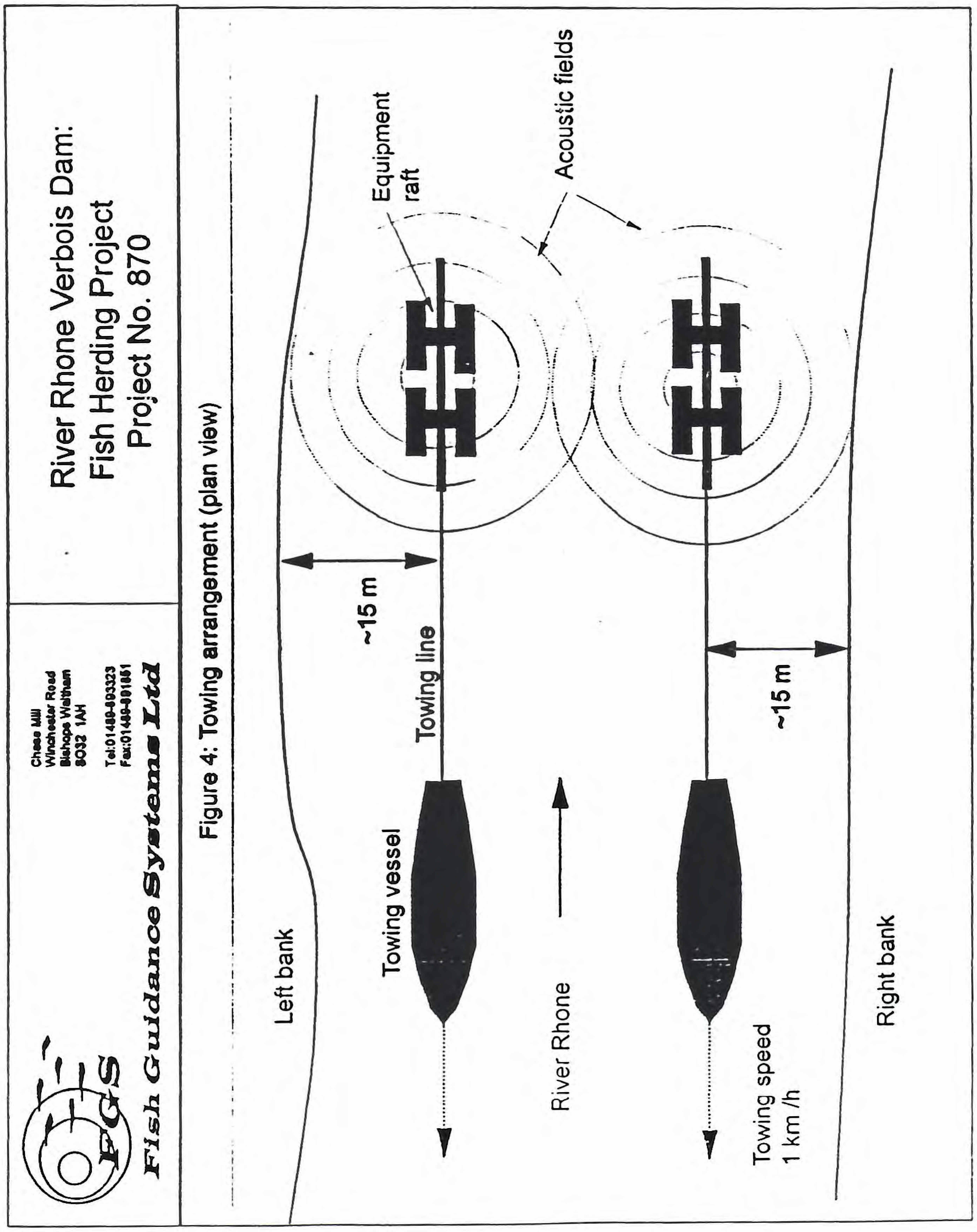


Figure 4

Illustration of SPA positioning between bridge piers.

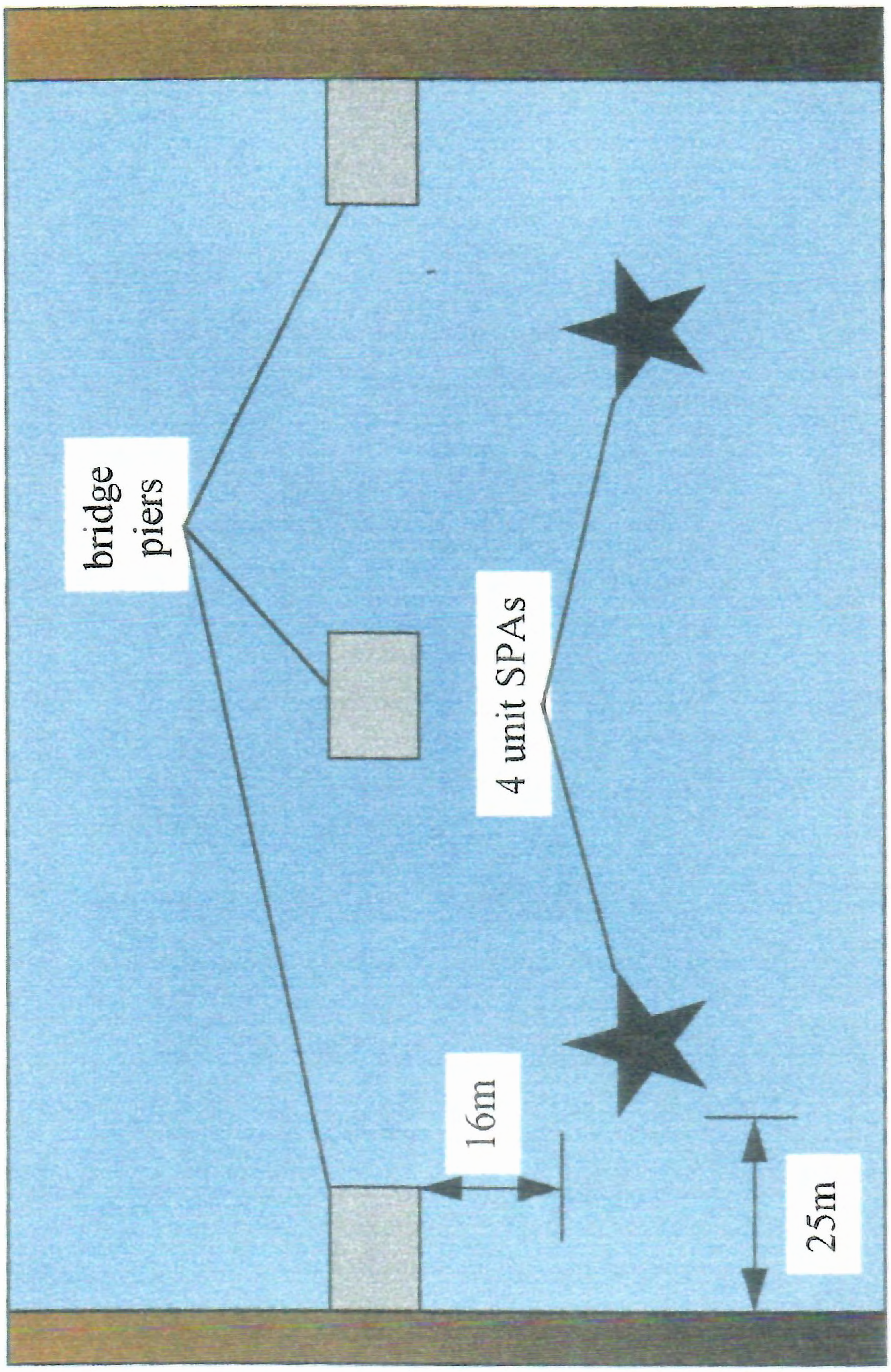


Figure 5

Contour map showing signal to noise levels for a single unit SPA located at position 12 on the River Rhône (transmitted frequency 100 Hz survey depth 3.5 metres).

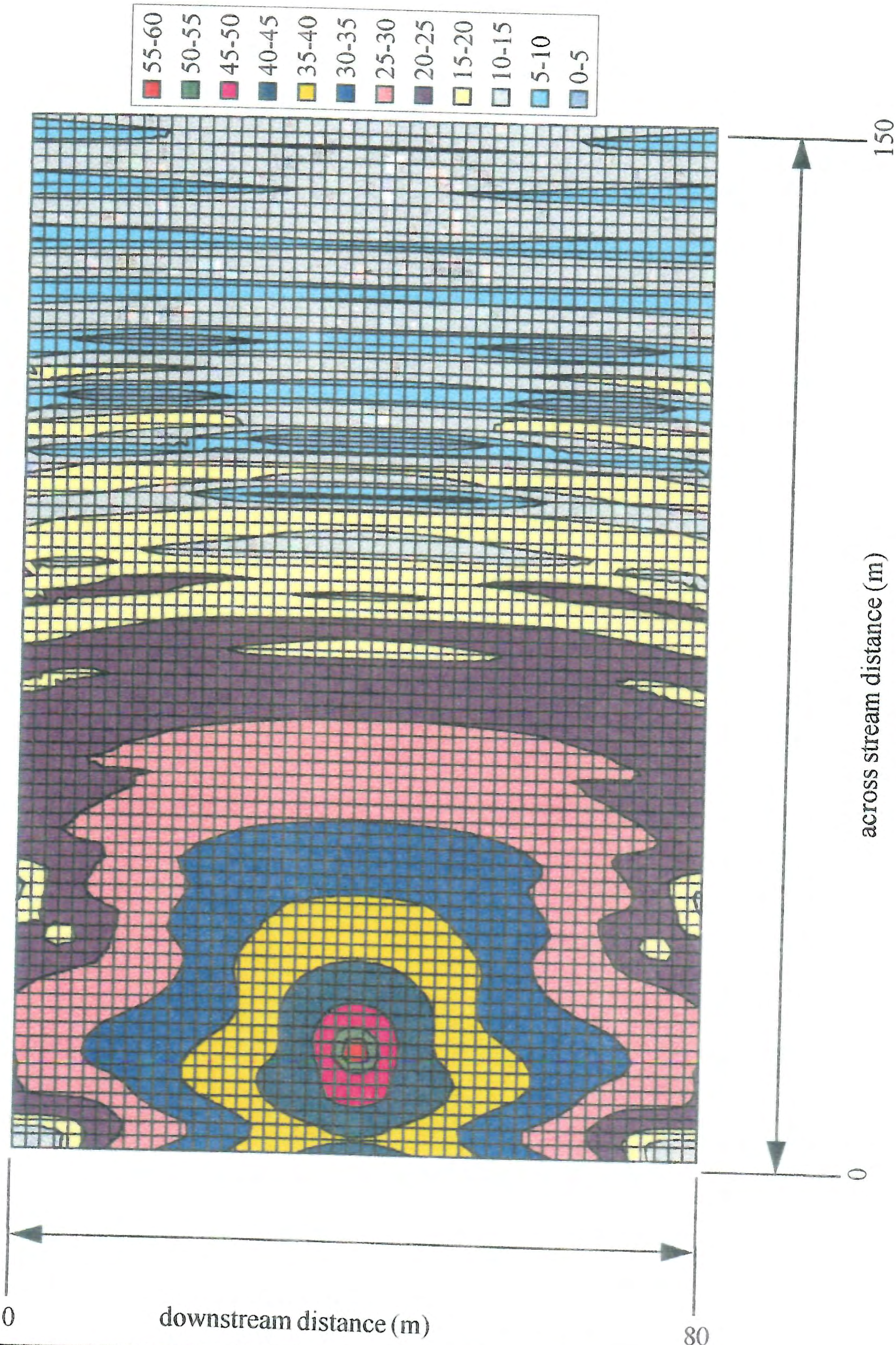


Figure 6

<u>Contour map showing signal to noise levels for a single unit SPA located at position 12 on the River Rhône (transmitted frequency 100 Hz survey depth 3.5 metres).</u>

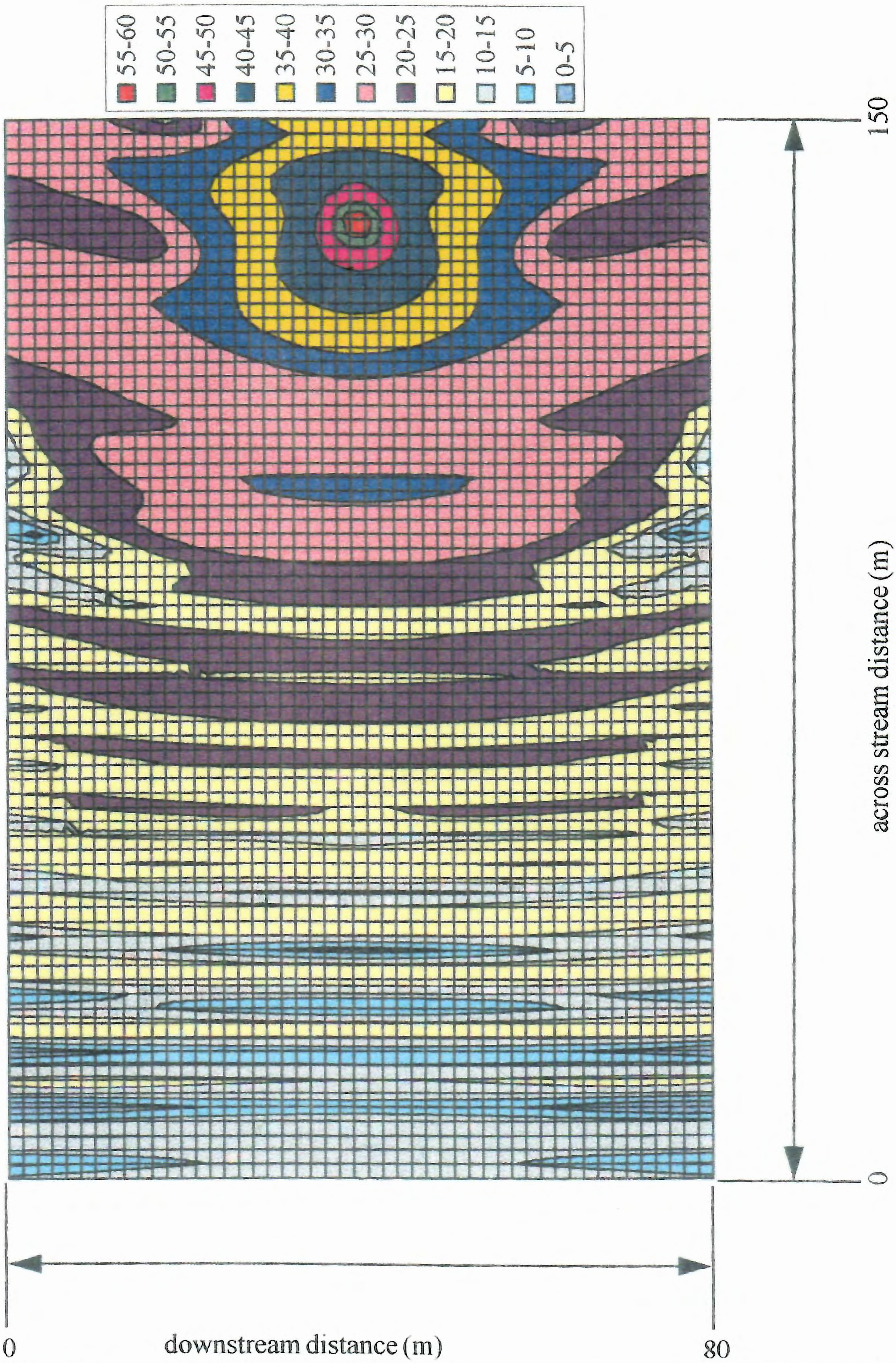


Figure 7

Contour map showing signal to noise levels for a 4 unit SPA located at position 12 on the River Rhône (transmitted frequency 100 Hz survey depth 3.5 metres).

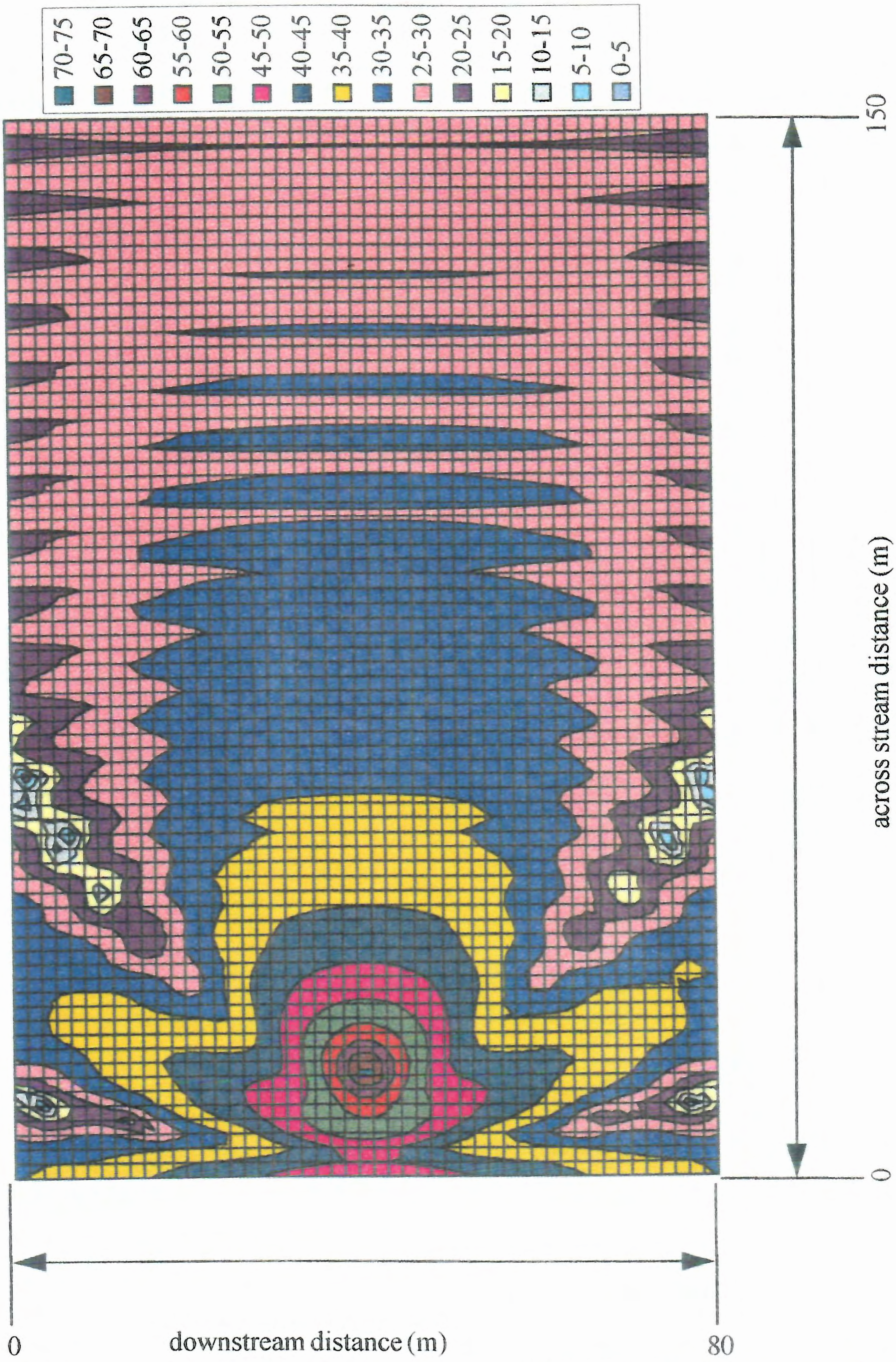


Figure 8

Contour map showing signal to noise levels for two single unit SPAs located at position 12 on the River Rhône (transmitted frequency 100 Hz survey depth 3.5 metres).

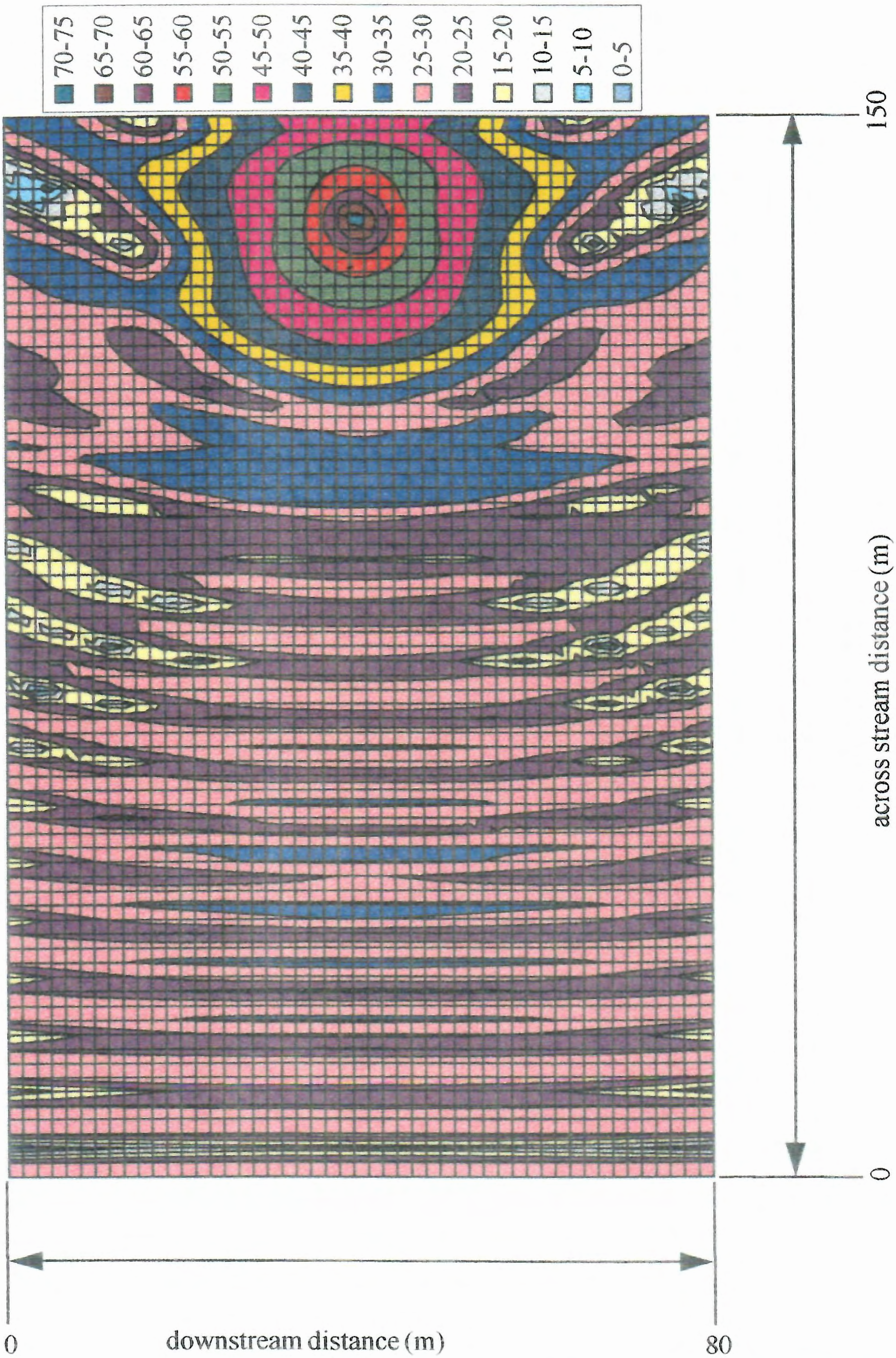


Figure 9

Contour map showing signal to noise levels for a 4 unit SPA located at position 12 on the River Rhône (transmitted frequency 100 Hz survey depth 3.5 metres).

Figure 10

Contour map showing signal to noise levels for a 4 unit SPA located at position 12 on the River Rhône (transmitted frequency 100 Hz survey depth 3.5 metres).

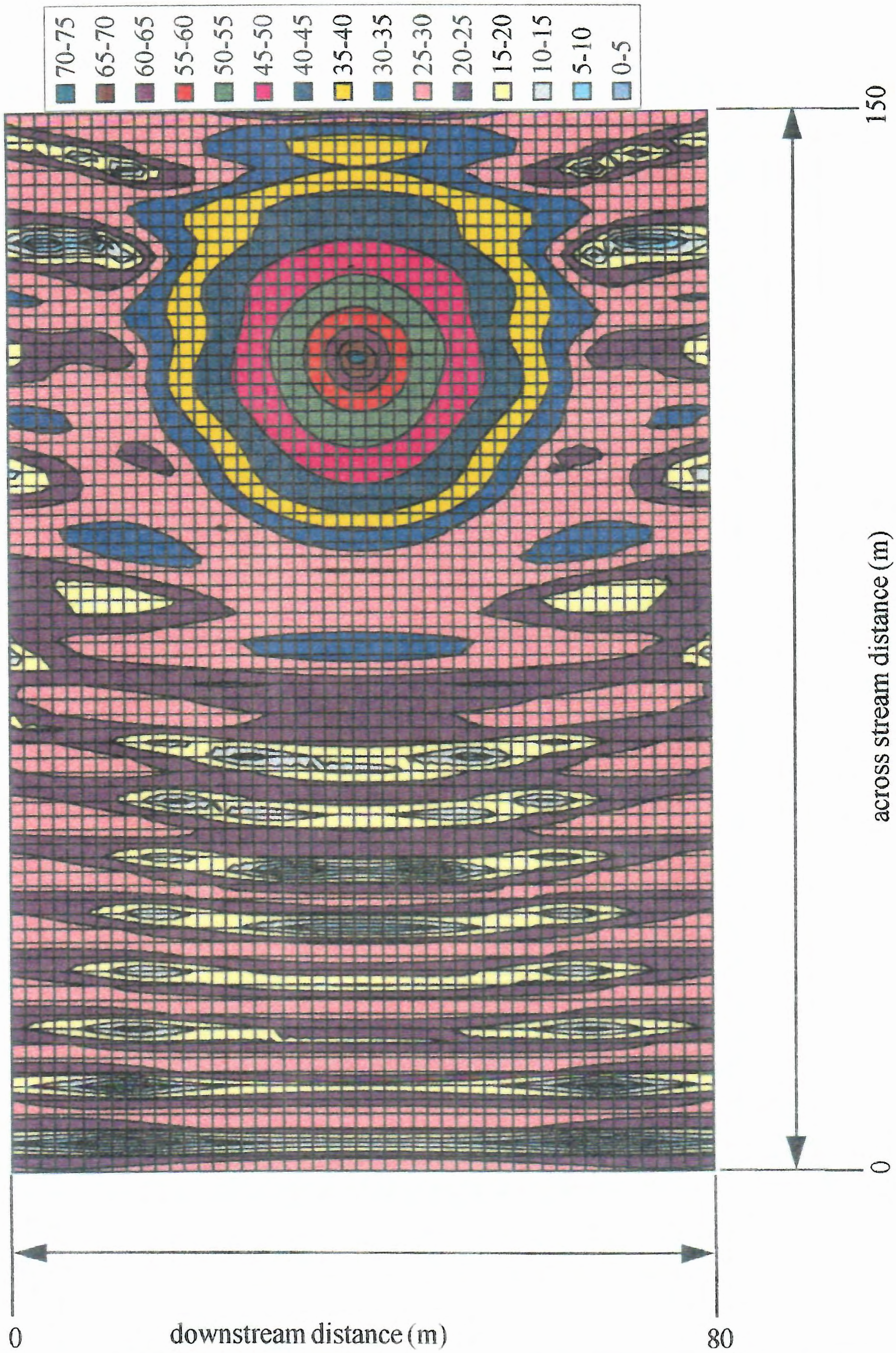


Figure 11

Contour map showing signal to noise levels for a 4 unit SPA located at position 12 on the River Rhône (transmitted frequency 100 Hz survey depth 3.5 metres).

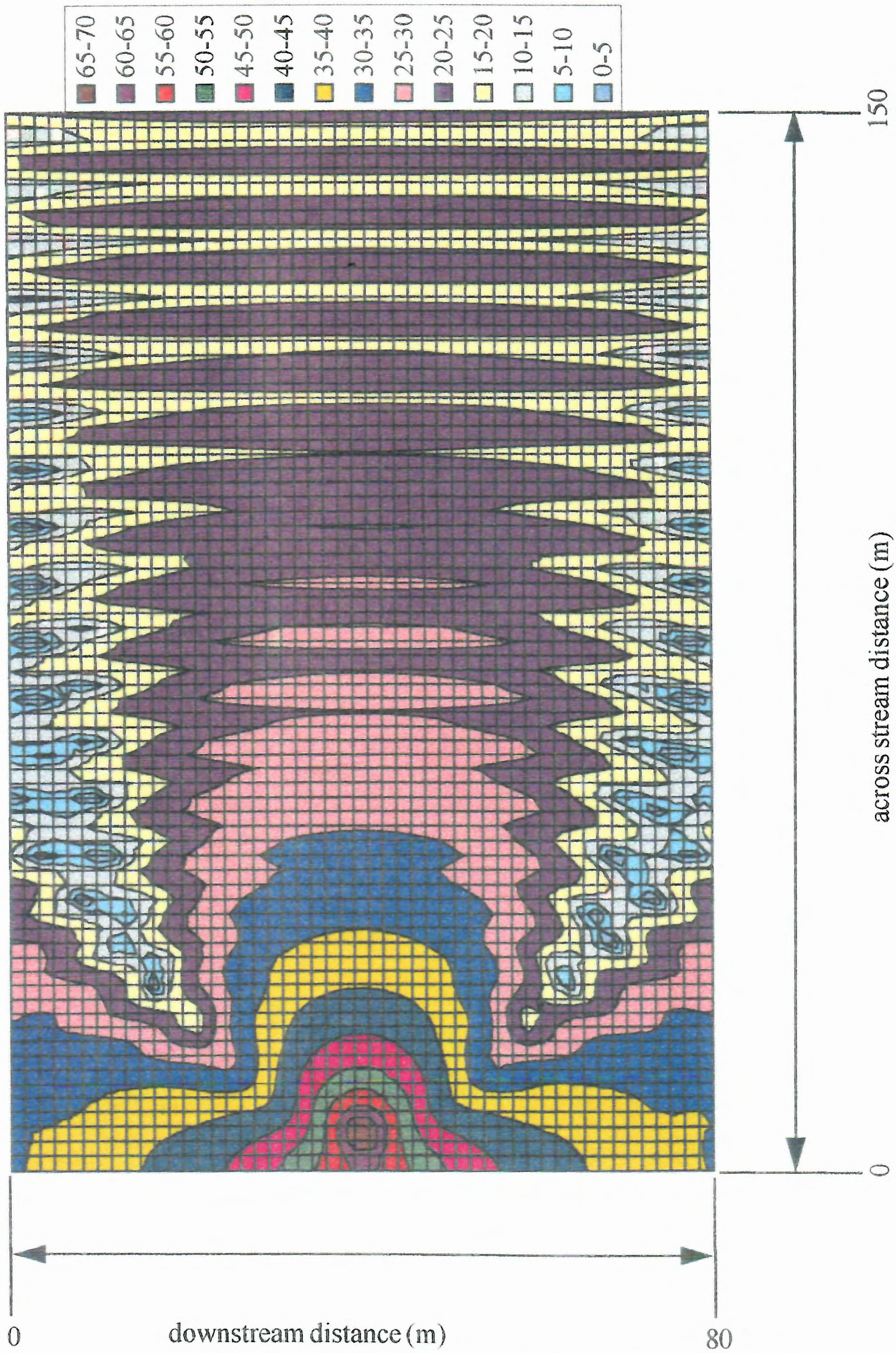


Figure 12

Contour map showing signal to noise levels for a 4 unit SPA located at position 12 on the River Rhône (transmitted frequency 100 Hz survey depth 3.5 metres).

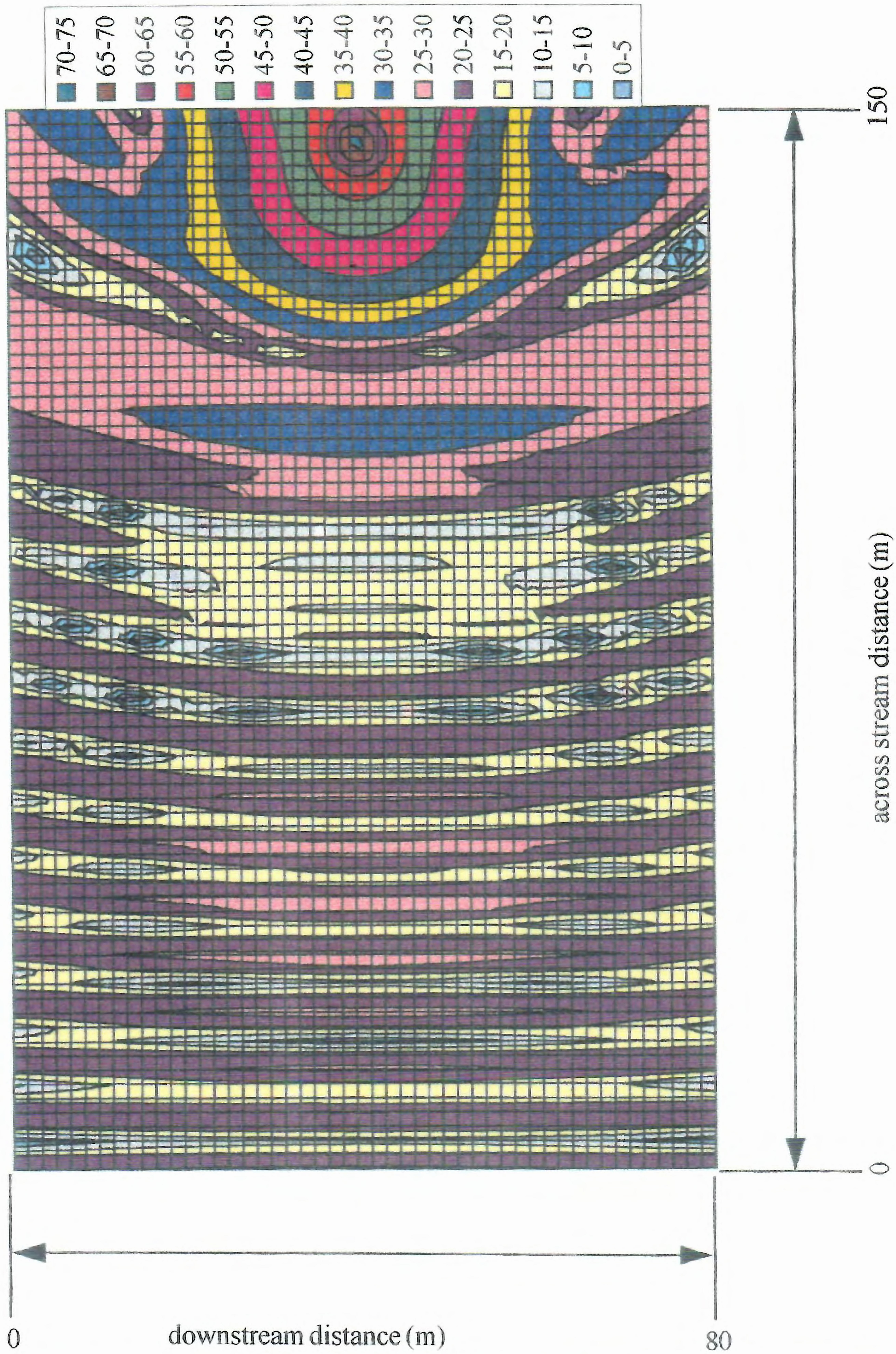


Figure 13

Contour map showing signal to noise levels for a 4 unit SPA located at position 12 on the River Rhône (transmitted frequency 50 Hz survey depth 3.5 metres).

Figure 14

Contour map showing signal to noise levels for a 4 unit SPA located at position 12 on the River Rhône (transmitted frequency 50 Hz survey depth 3.5 metres).

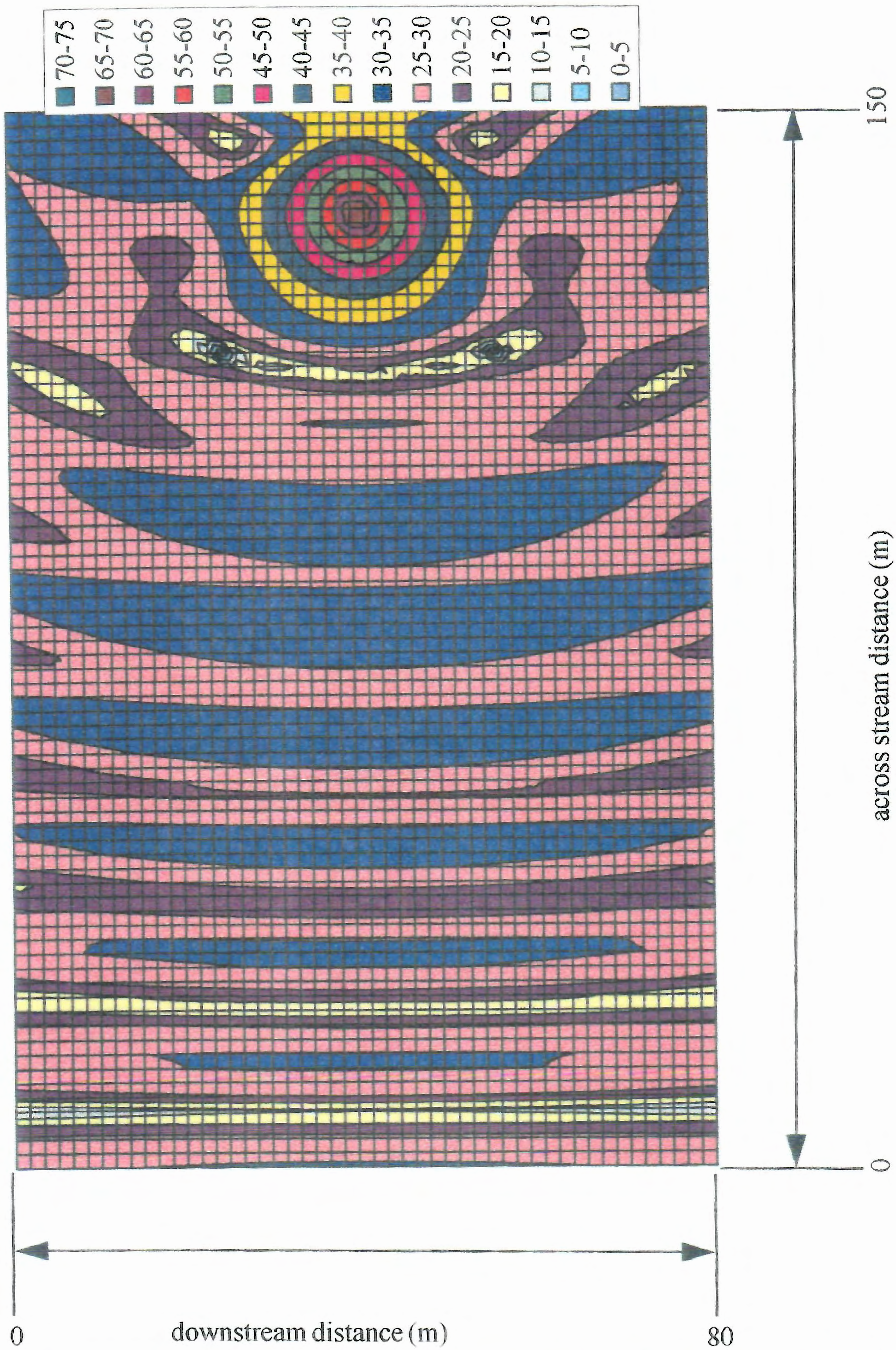


Figure 15

Contour map showing signal to noise levels for a 4 unit SPA located at position 12 on the River Rhône (transmitted frequency 300 Hz survey depth 3.5 metres).

Figure 16

Contour map showing signal to noise levels for a 4 unit SPA located at position 12 on the River Rhône (transmitted frequency 300 Hz survey depth 3.5 metres).

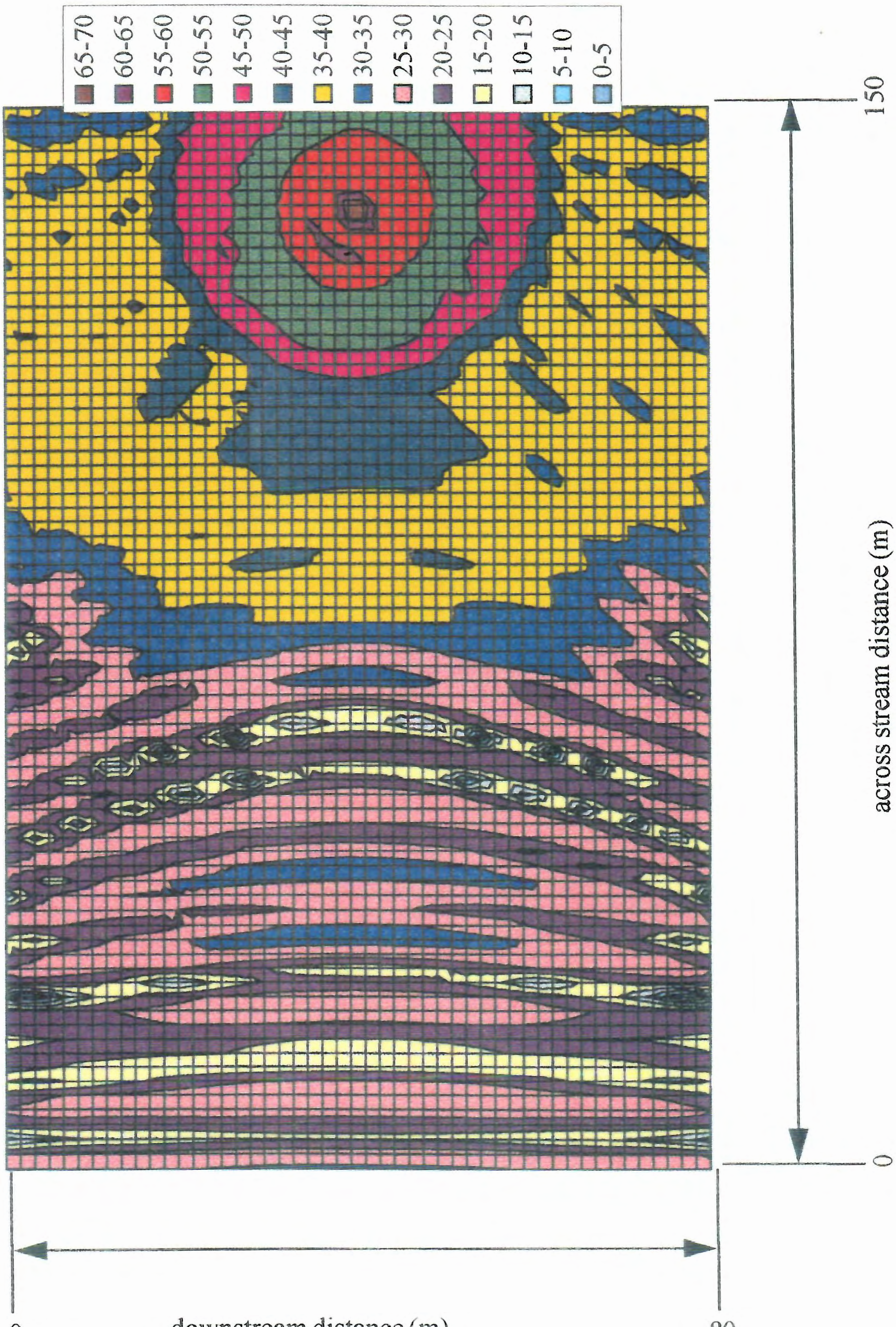


Figure 17

Contour map showing signal to noise levels for a 4 unit SPA located at position 12 on the River Rhône (transmitted frequency 100 Hz survey depth 1.5 metres).

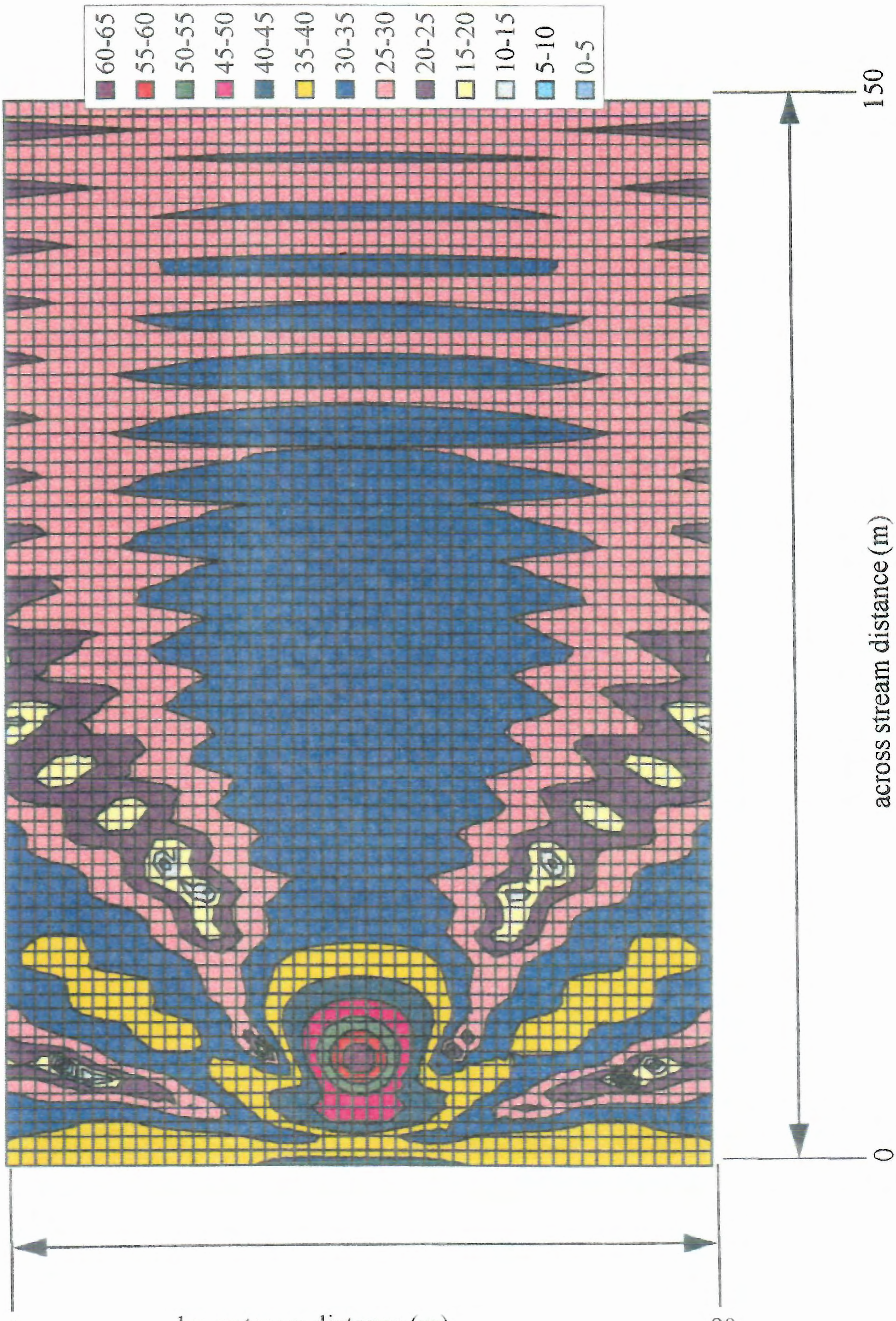


Figure 18

Contour map showing signal to noise levels for a 4 unit SPA located at position 12 on the River Rhône (transmitted frequency 100 Hz survey depth 1.5 metres).

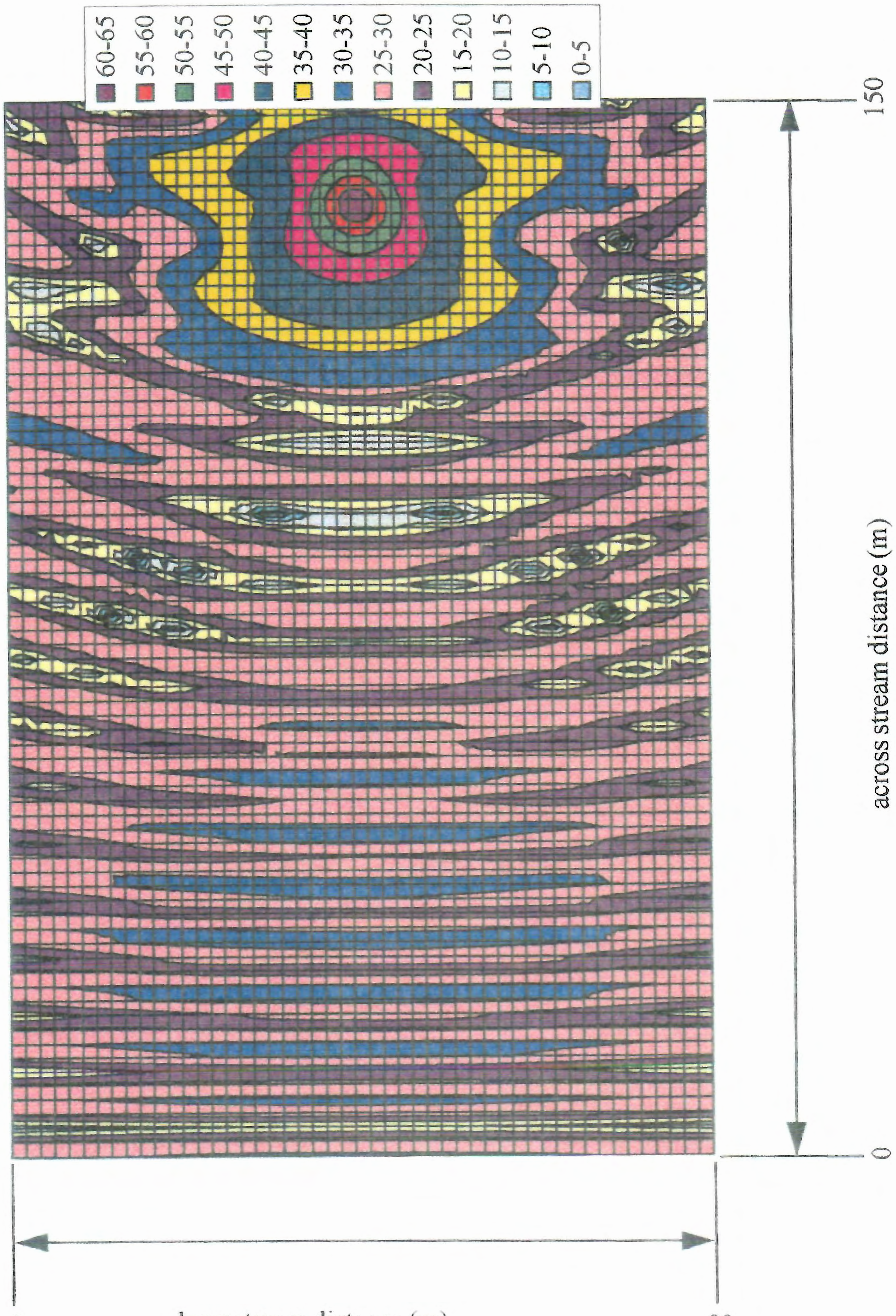


Figure 19

Contour map showing signal to noise levels for a 4 unit SPA located at position 12 on the River Rhône (transmitted frequency 100 Hz survey depth 5.5 metres).

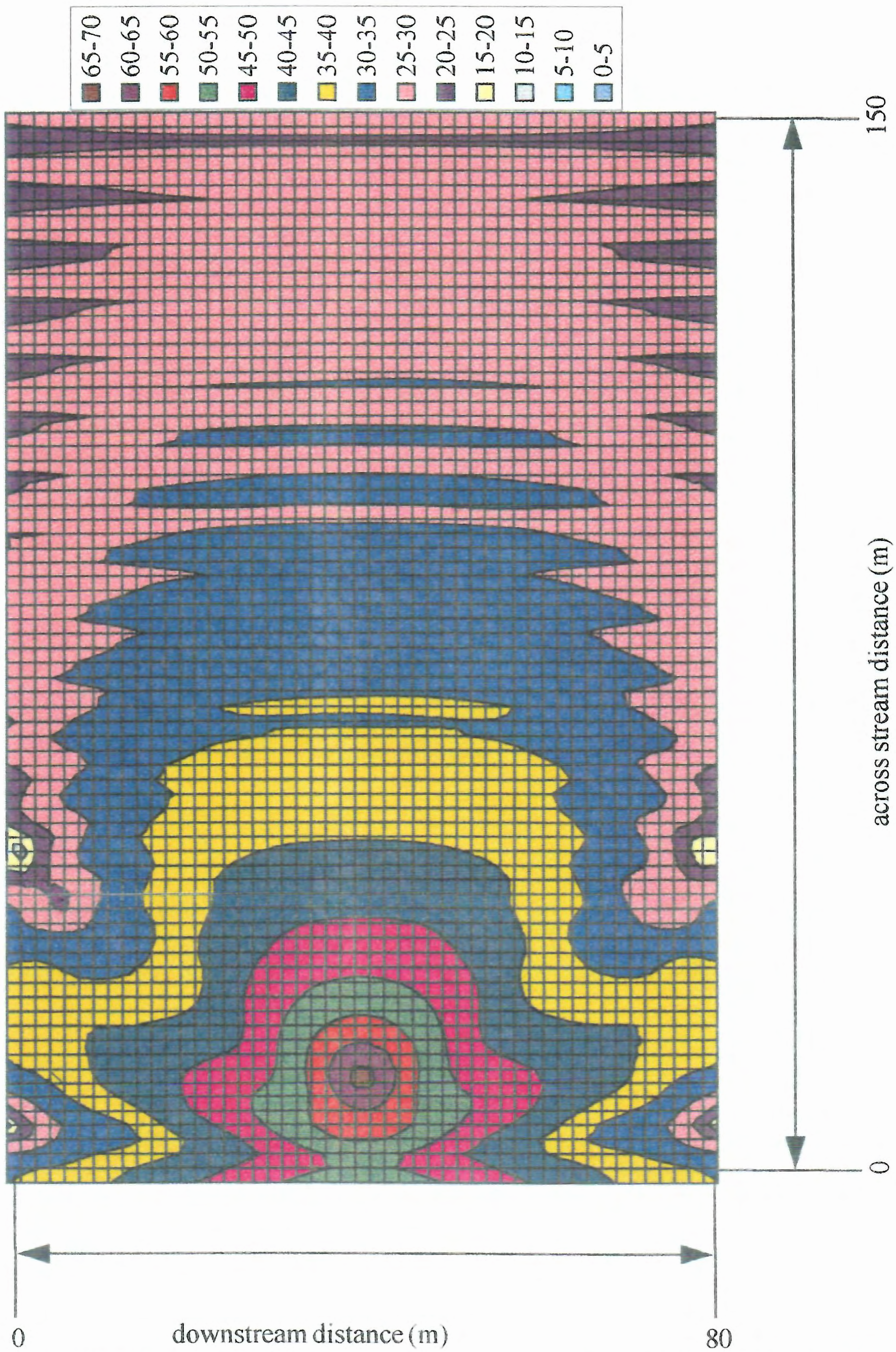


Figure 20

Contour map showing signal to noise levels for a 4 unit SPA located at position 12 on the River Rhône (transmitted frequency 100 Hz survey depth 5.5 metres).

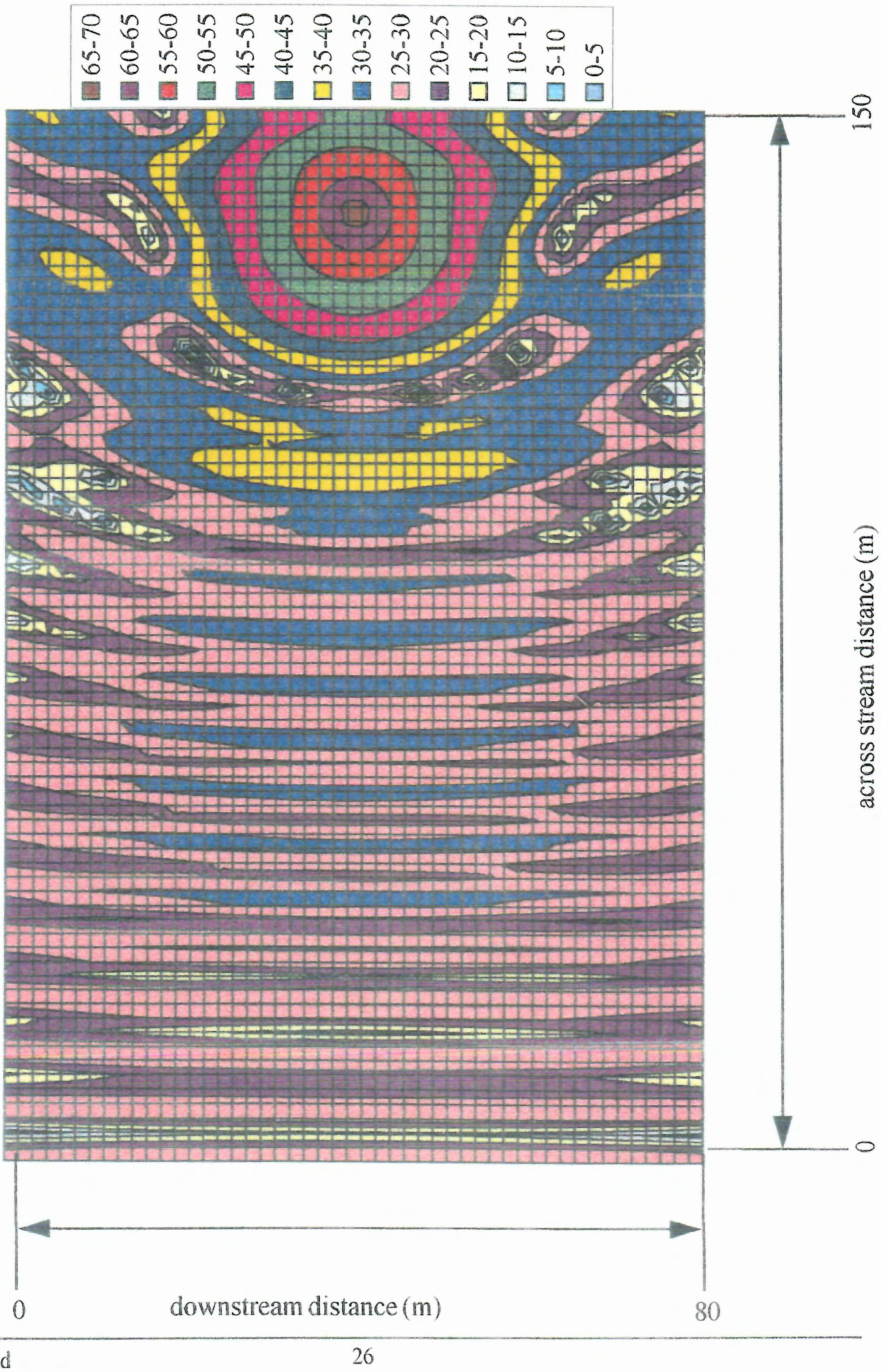


Figure 21

Contour map showing signal to noise levels for a 4 unit SPA located at position 12 on the River Rhône (transmitted frequency 100 Hz survey depth 3.5 metres).

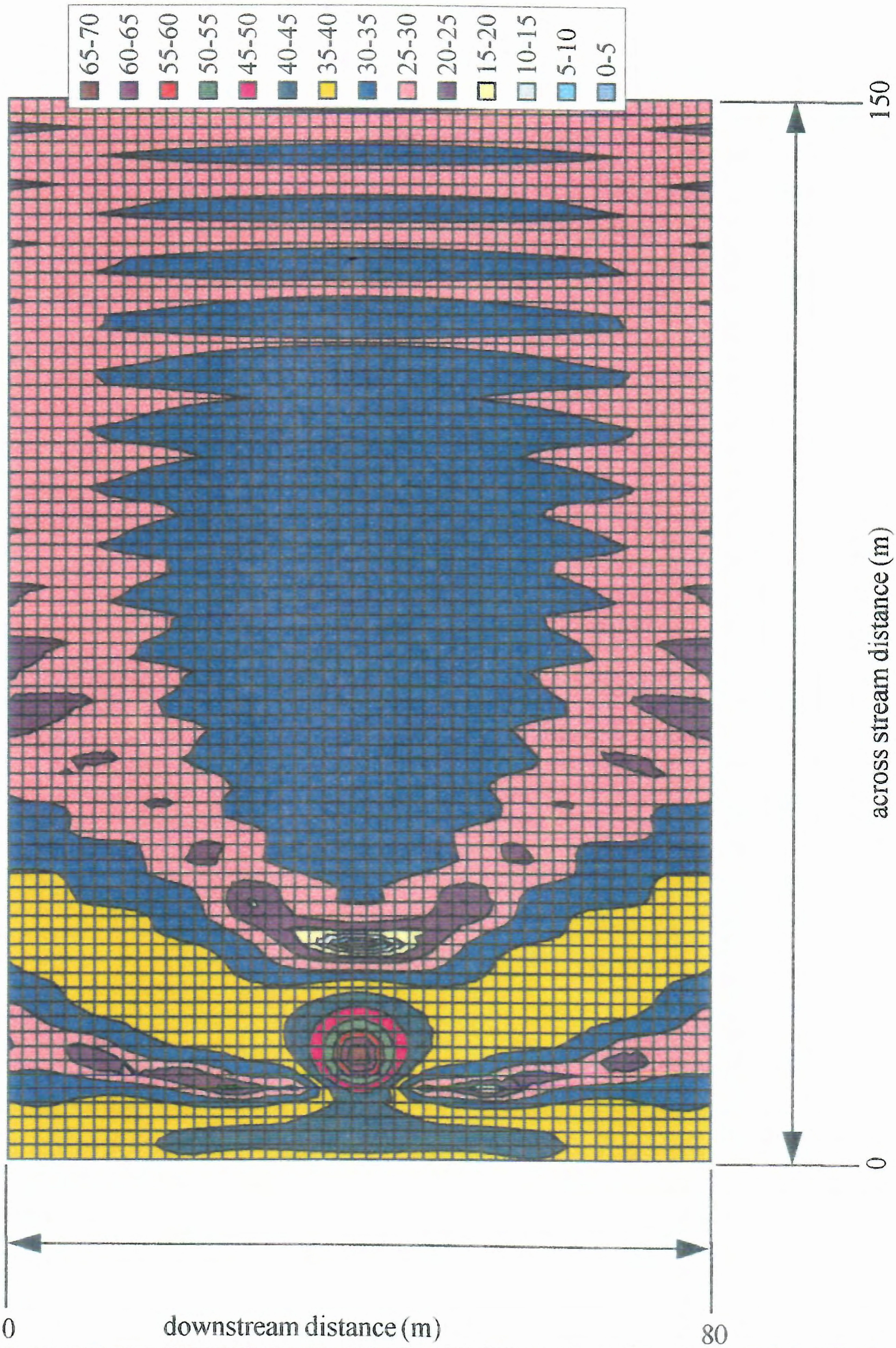


Figure 22

Contour map showing signal to noise levels for a 4 unit SPA located at position 12 on the River Rhône (transmitted frequency 100 Hz survey depth 3.5 metres).

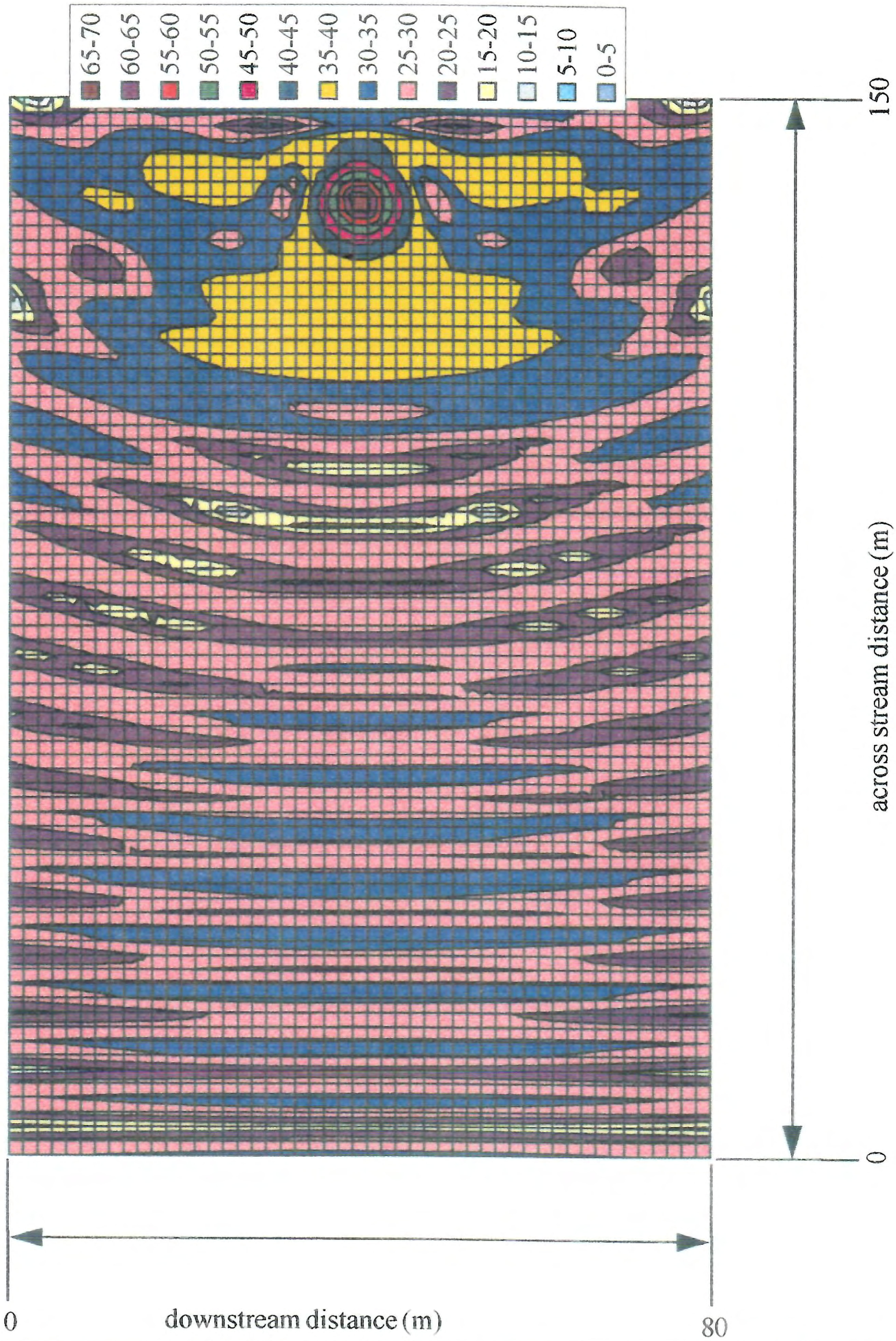


Figure 23

Contour map showing signal to noise levels for a 4 unit SPA located at position 12 on the River Rhône (transmitted frequency 100 Hz survey depth 3.5 metres).

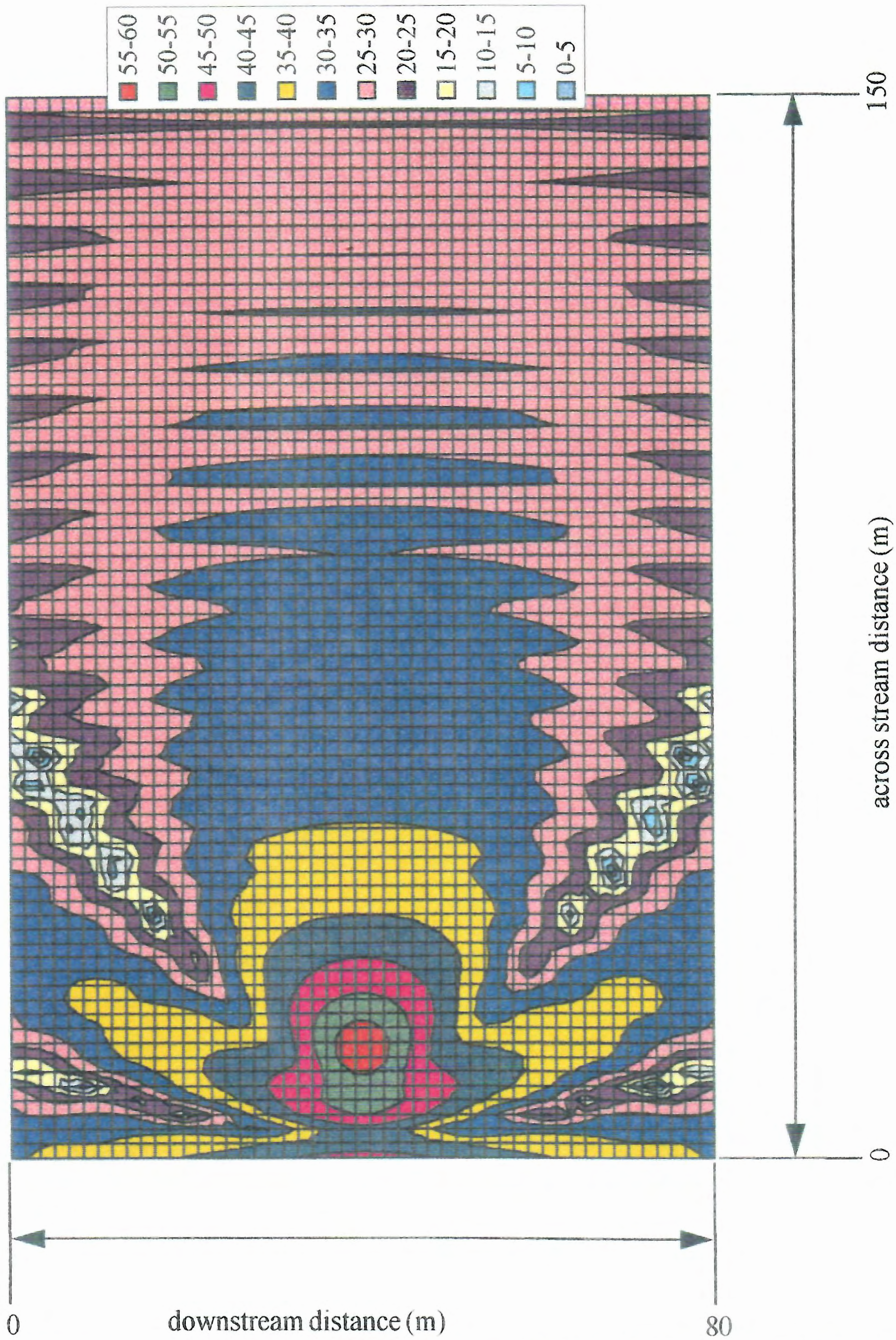


Figure 24

Contour map showing signal to noise levels for a 4 unit SPA located at position 12 on the River Rhône (transmitted frequency 100 Hz survey depth 3.5 metres).

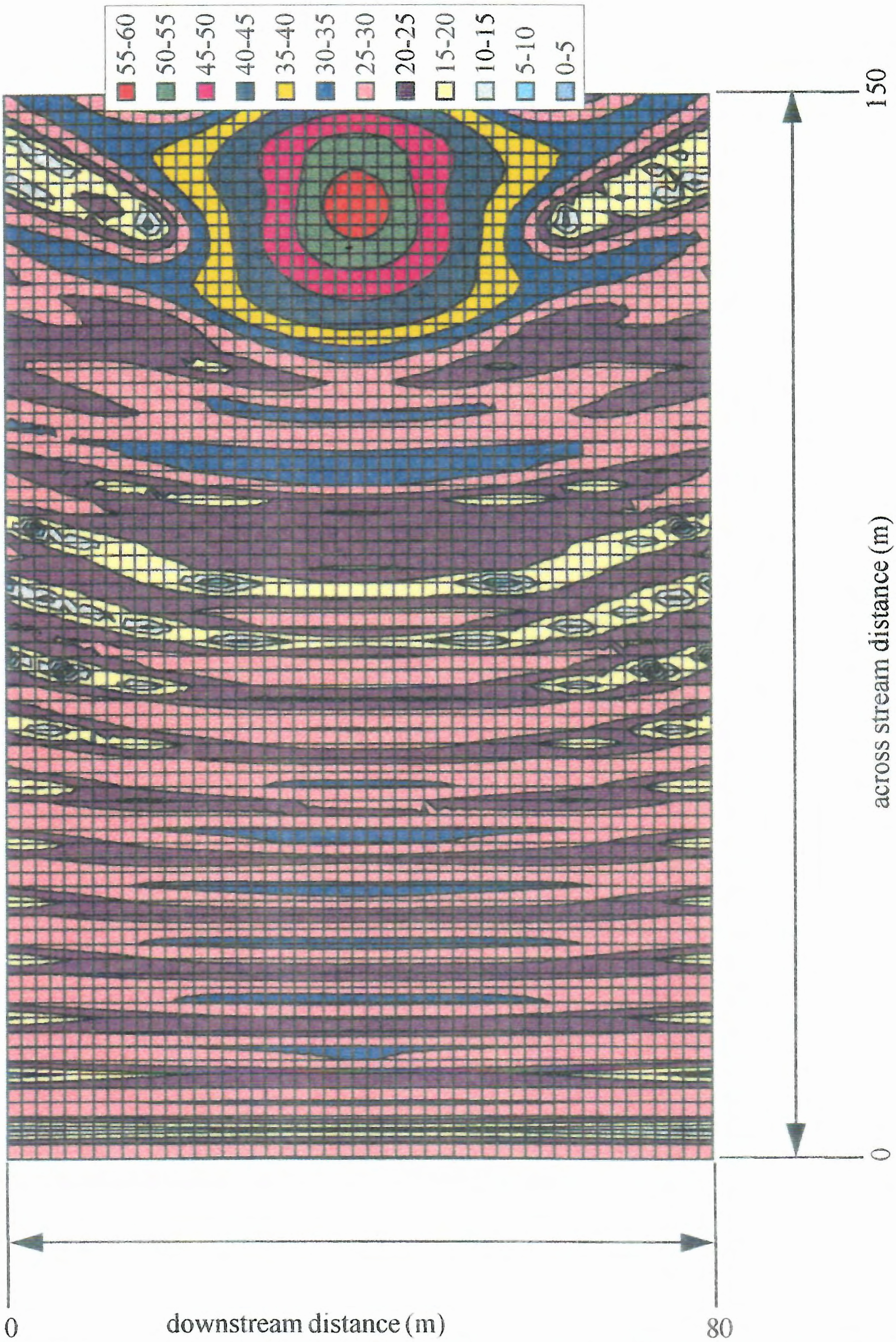


Figure 25

Contour map showing signal to noise levels for a 4 unit SPA located at position 6.1 on the River Rhône (transmitted frequency 100 Hz survey depth 1.5 metres).

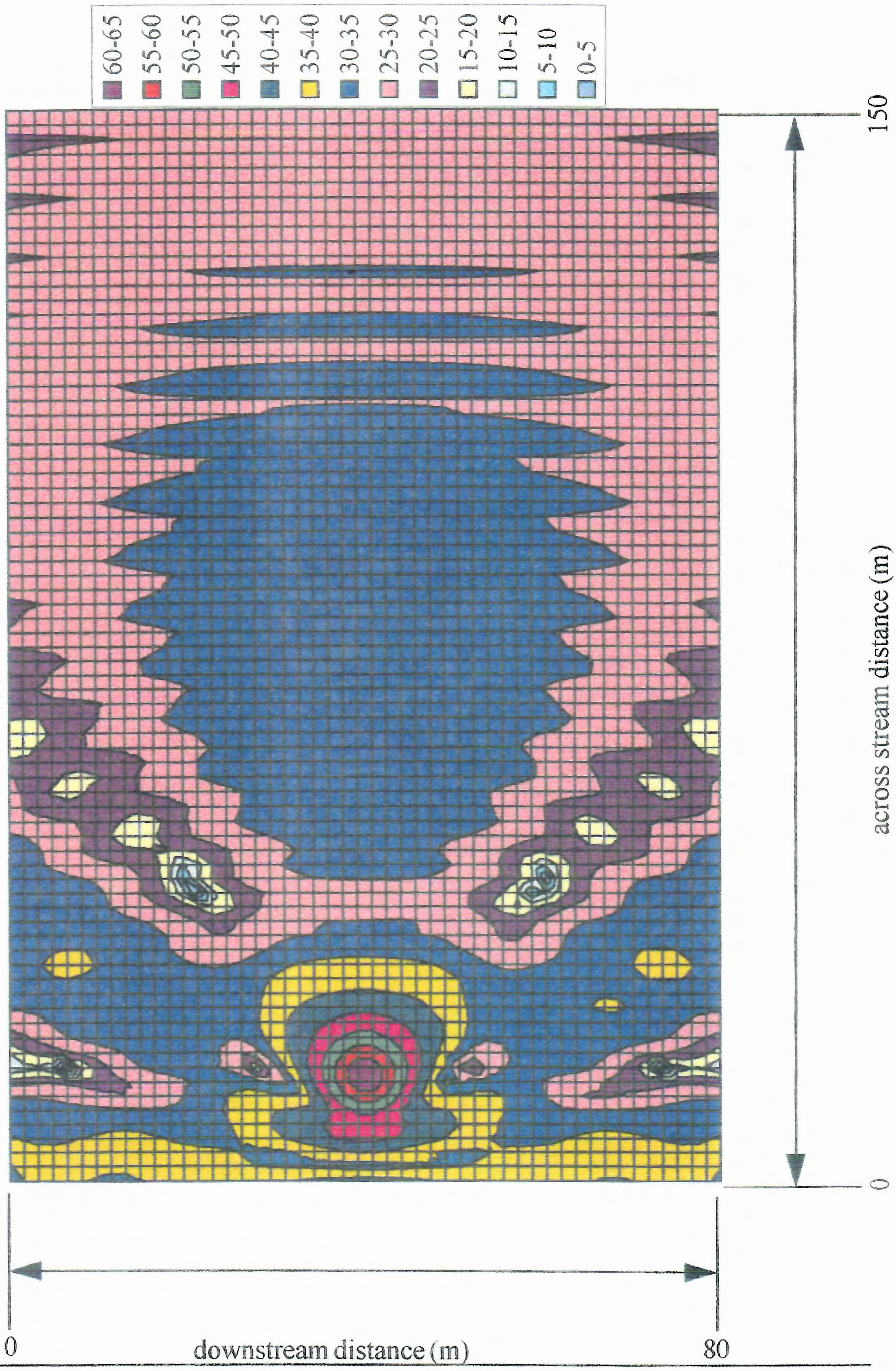


Figure 26

Contour map showing signal to noise levels for a 4 unit SPA located at position 6.1 on the River Rhône (transmitted frequency 100 Hz survey depth 1.5 metres).

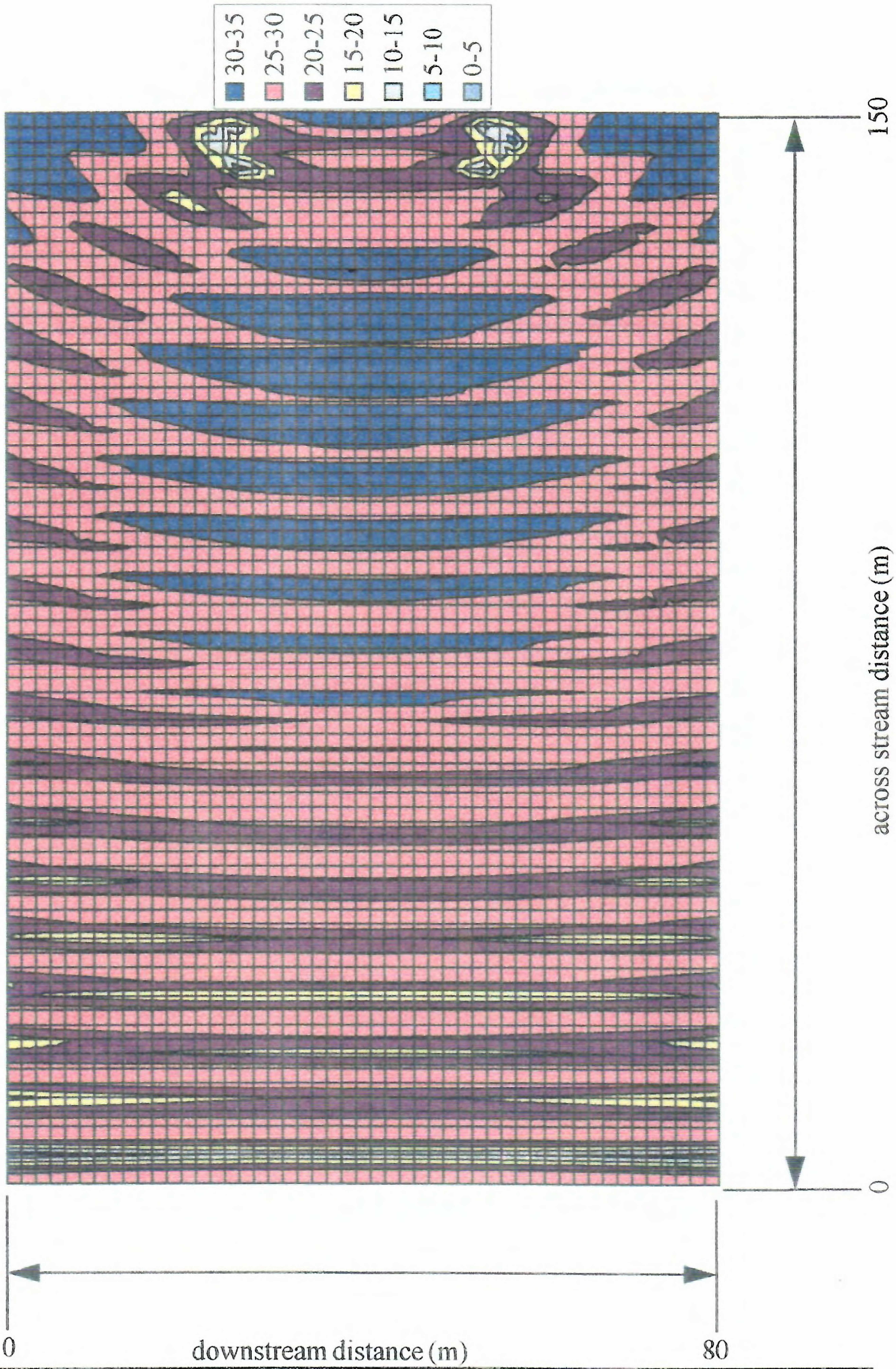


Figure 27

Contour map showing signal to noise levels for a 4 unit SPA located at position 6.1 on the River Rhône (transmitted frequency 100 Hz survey depth 3.5 metres).

Figure 28

Contour map showing signal to noise levels for a 4 unit SPA located at position 6.1 on the River Rhône (transmitted frequency 100 Hz survey depth 3.5 metres).

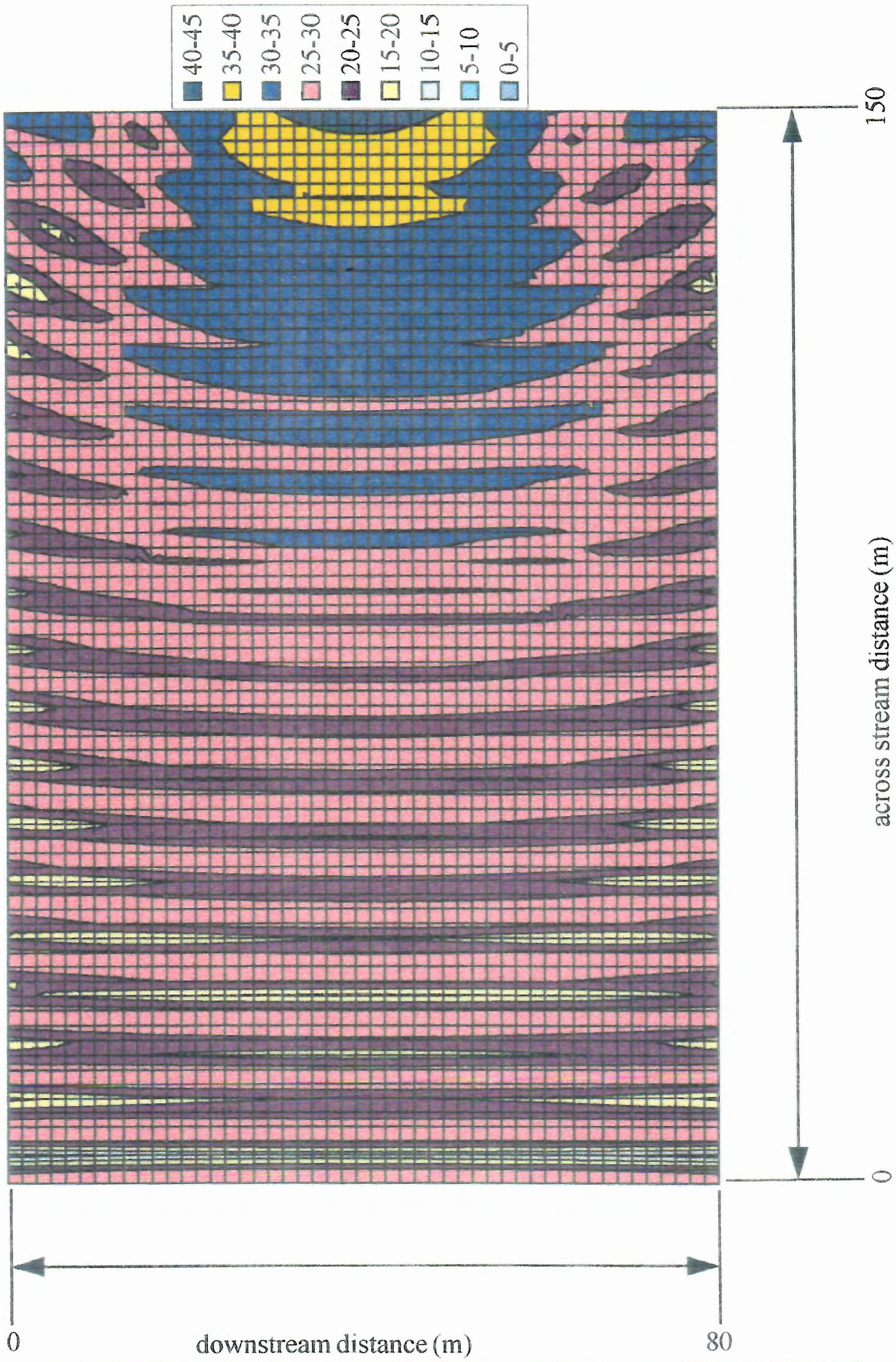


Figure 29

Contour map showing signal to noise levels for a 4 unit SPA located at position 6.1 on the River Rhône (transmitted frequency 100 Hz survey depth 5.5 metres).

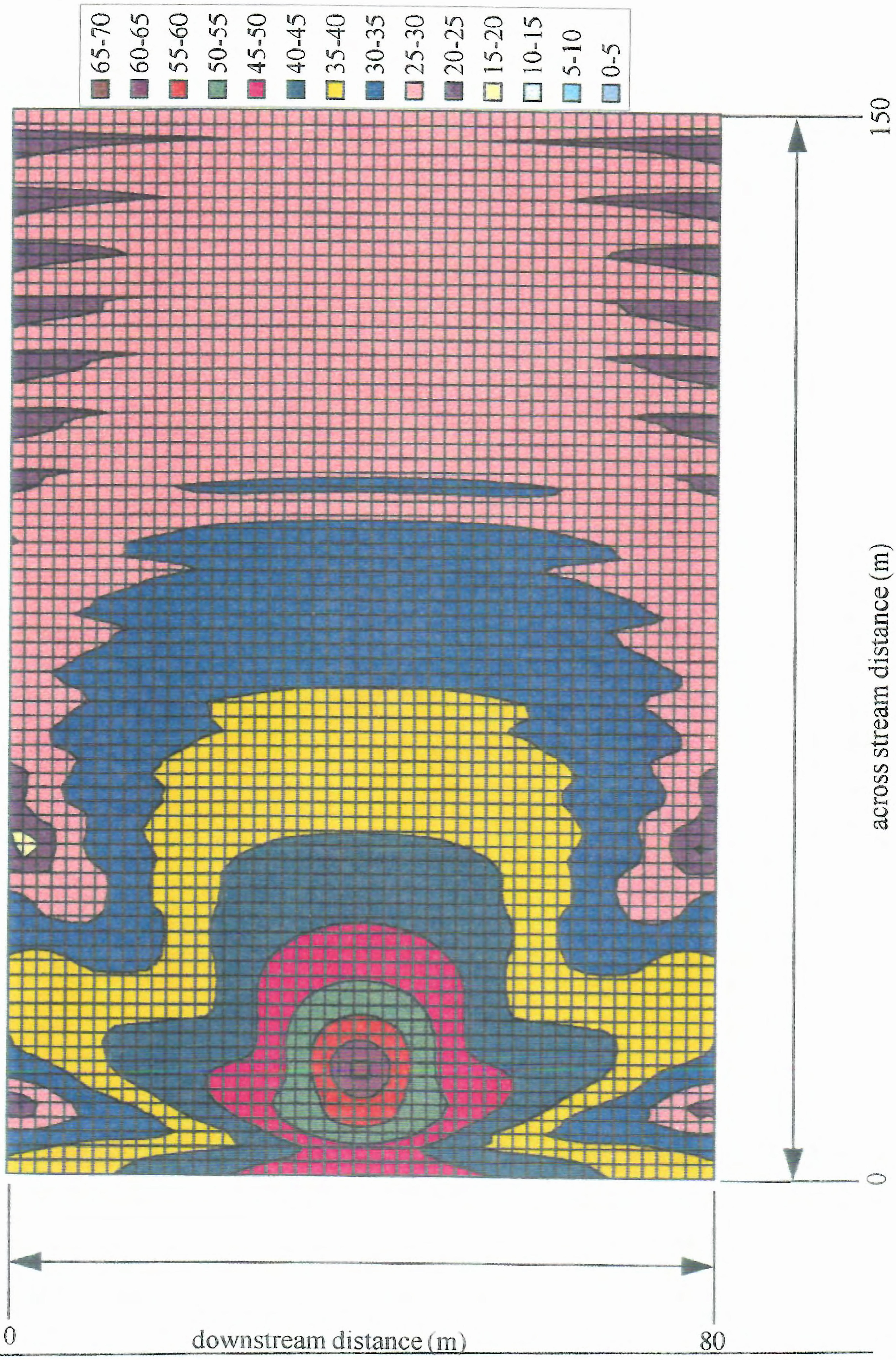


Figure 30

Contour map showing signal to noise levels for a 4 unit SPA located at position 6.1 on the River Rhône (transmitted frequency 100 Hz survey depth 5.5 metres).

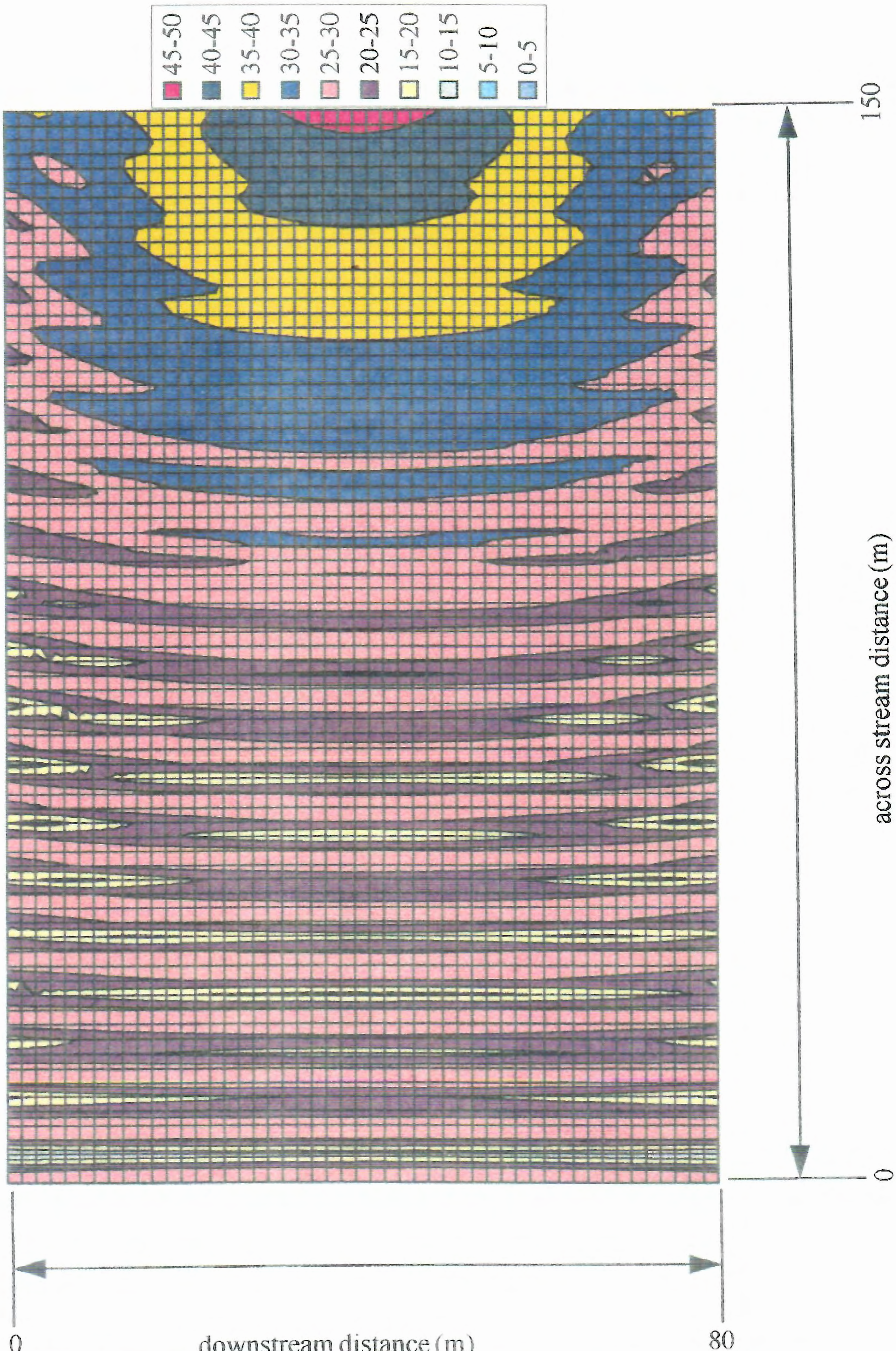


Figure 31

Contour map showing signal to noise levels for a 4 unit SPA located at the bridge piers on the River Rhône (transmitted frequency 100 Hz survey depth 1.5 metres).

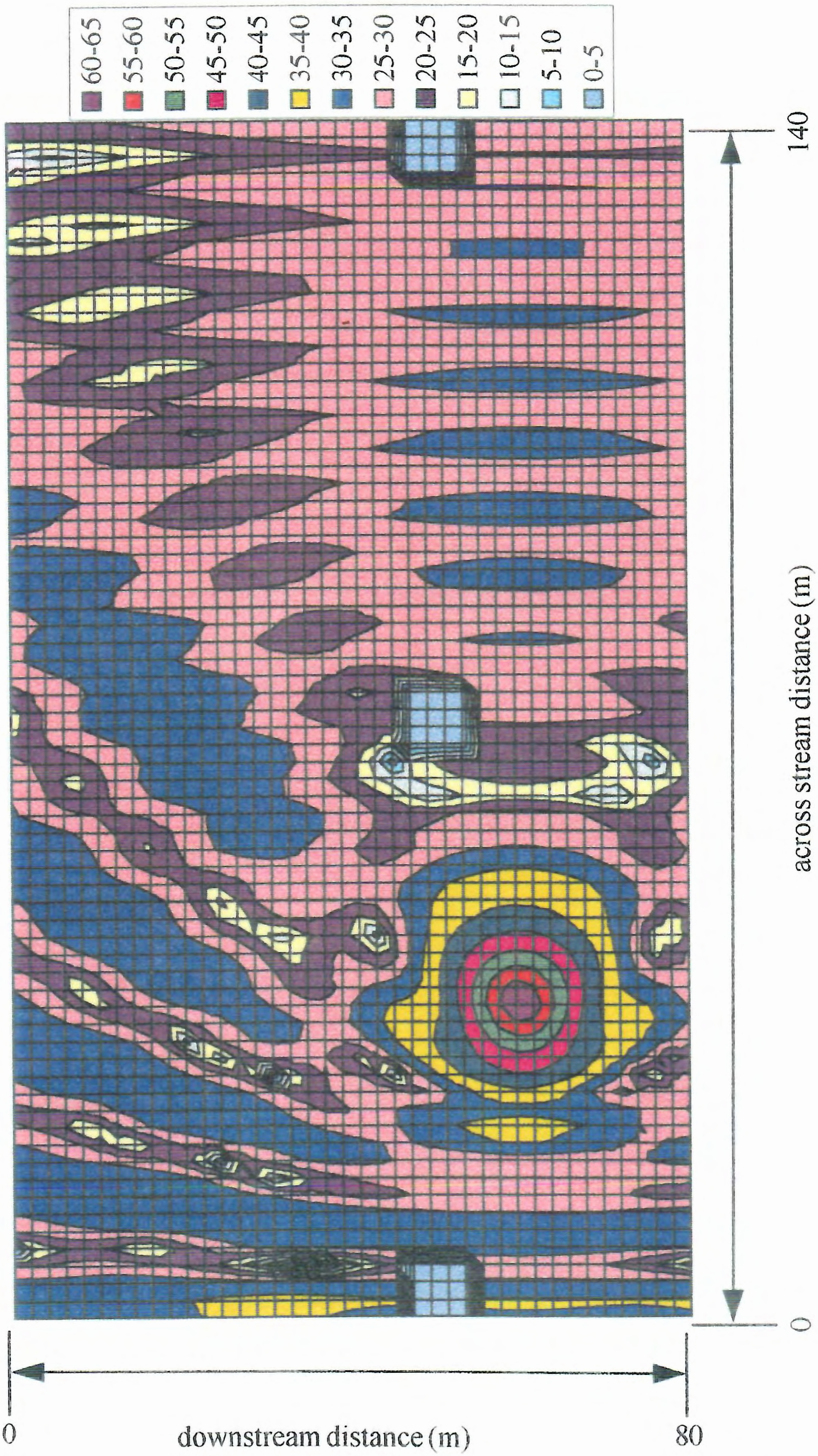


Figure 32

Contour map showing signal to noise levels for a 4 unit SPA located at the bridge piers on the River Rhône (transmitted frequency 100 Hz survey depth 1.5 metres).

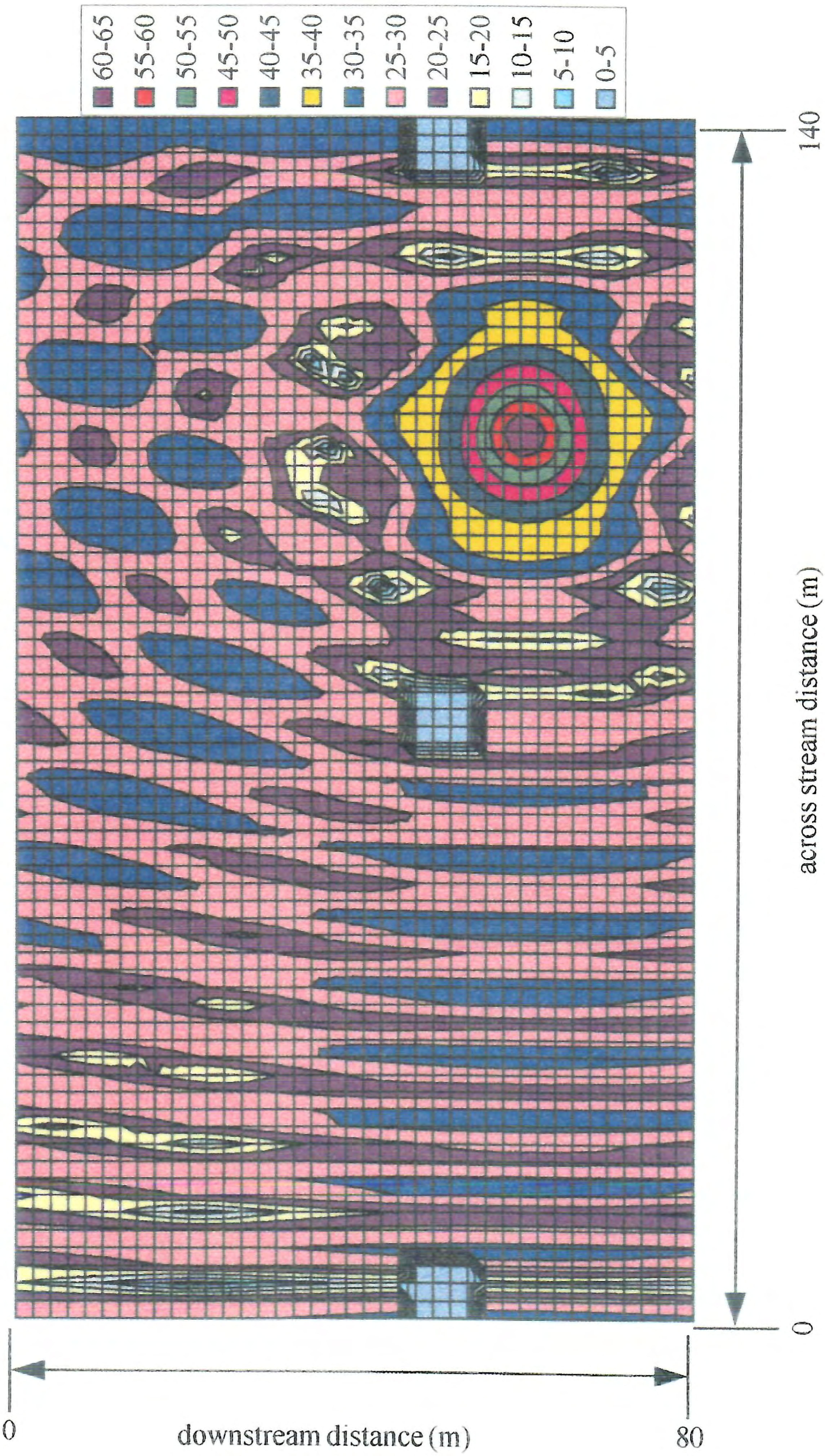


Figure 33

Contour map showing signal to noise levels for a 4 unit SPA located at the bridge piers on the River Rhône (transmitted frequency 100 Hz survey depth 3.5 metres).

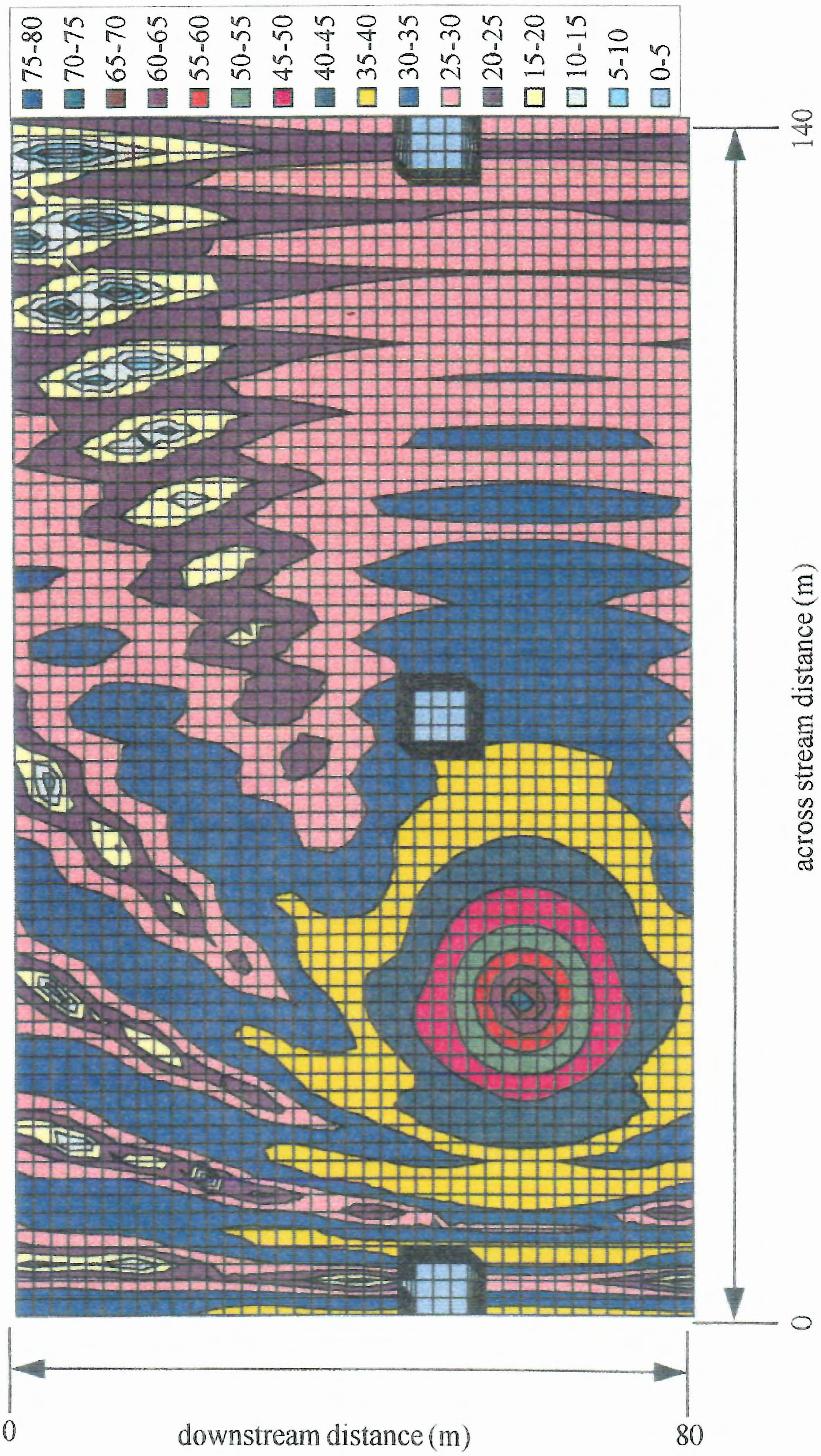


Figure 34

Contour map showing signal to noise levels for a 4 unit SPA located at the bridge piers on the River Rhône (transmitted frequency 100 Hz survey depth 3.5 metres).

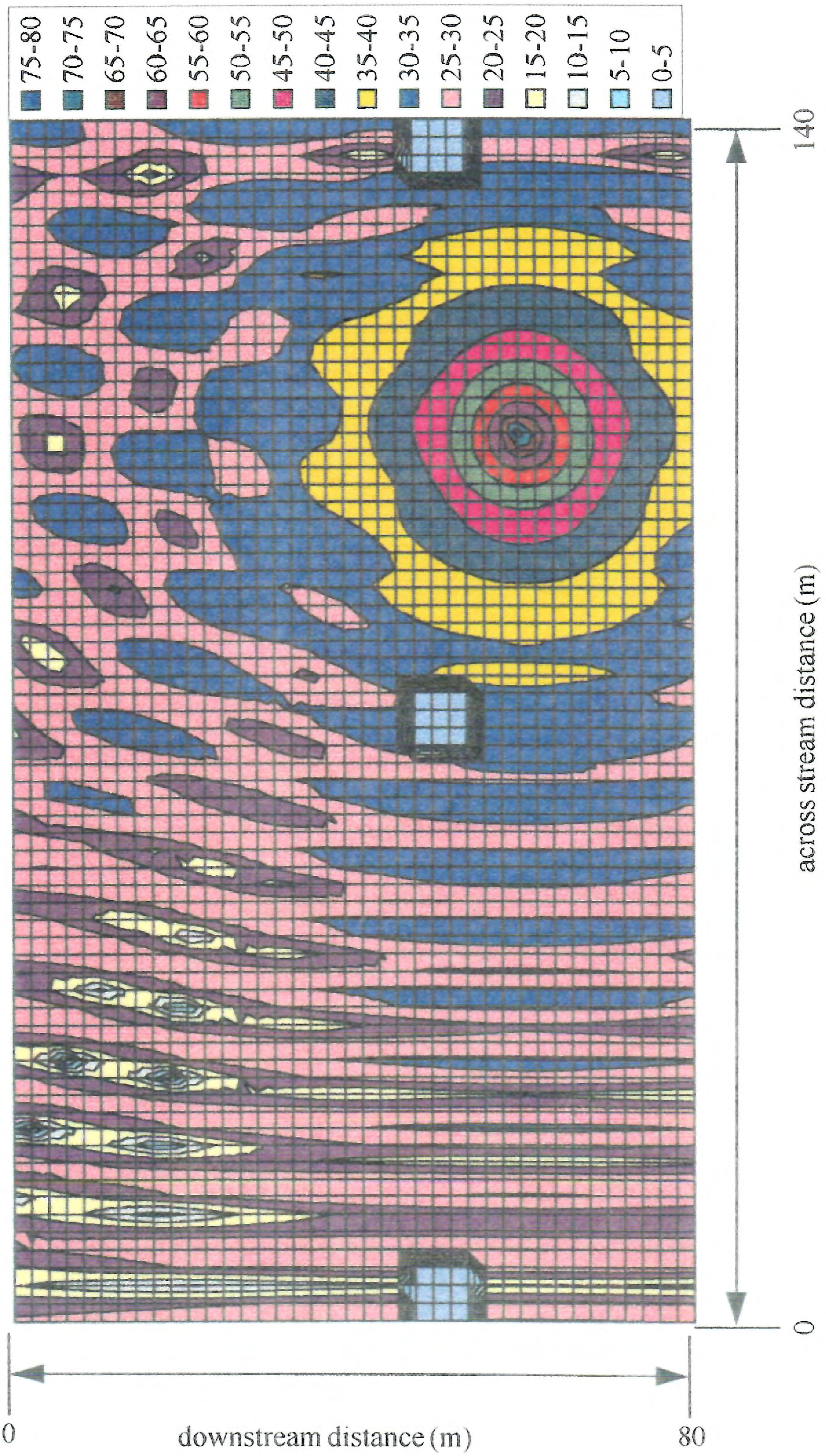


Figure 35

Contour map showing signal to noise levels for a 4 unit SPA located at the bridge piers on the River Rhône (transmitted frequency 100 Hz survey depth 5.5 metres).

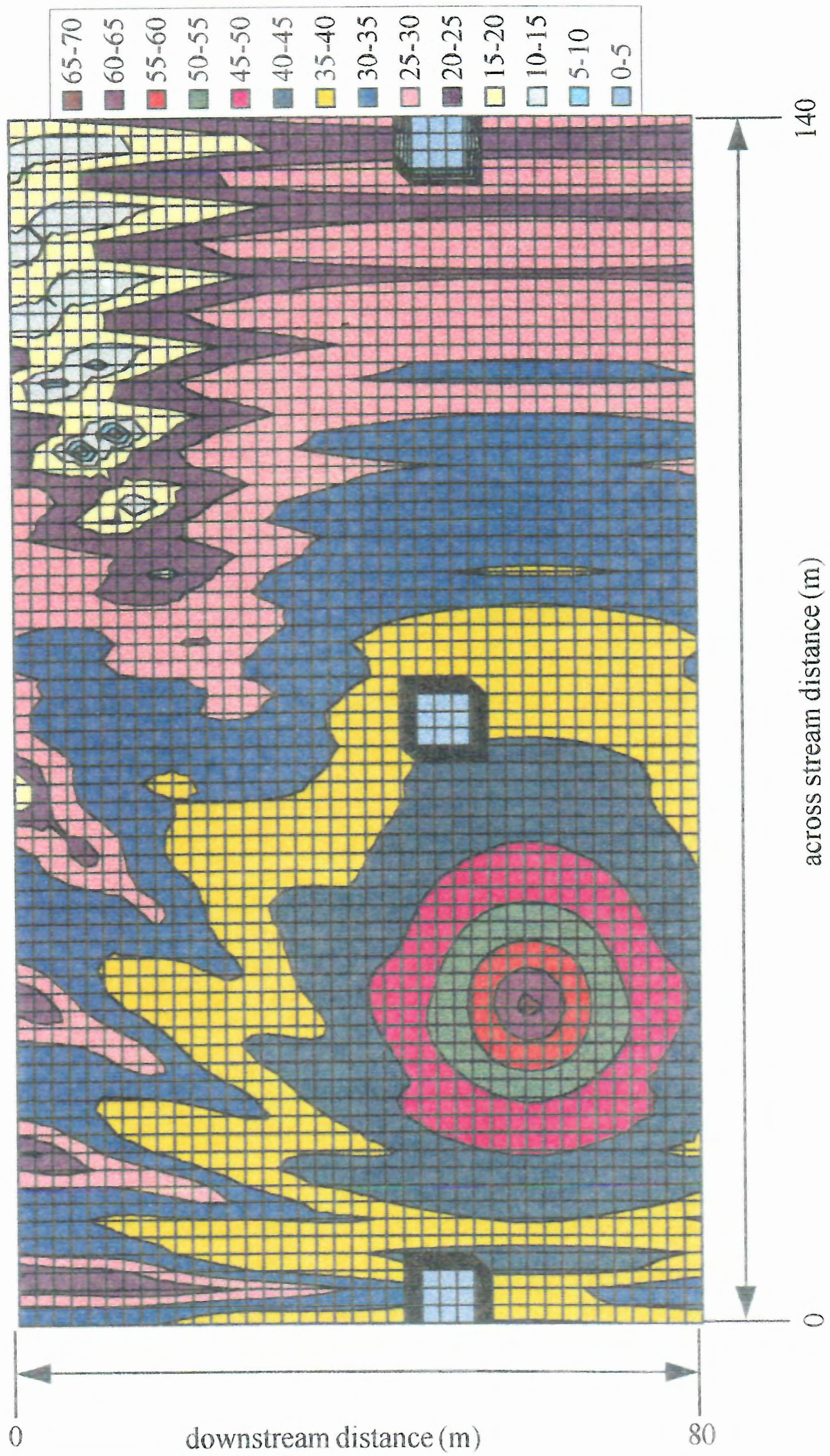


Figure 36

Contour map showing signal to noise levels for a 4 unit SPA located at the bridge piers on the River Rhône (transmitted frequency 100 Hz survey depth 5.5 metres).

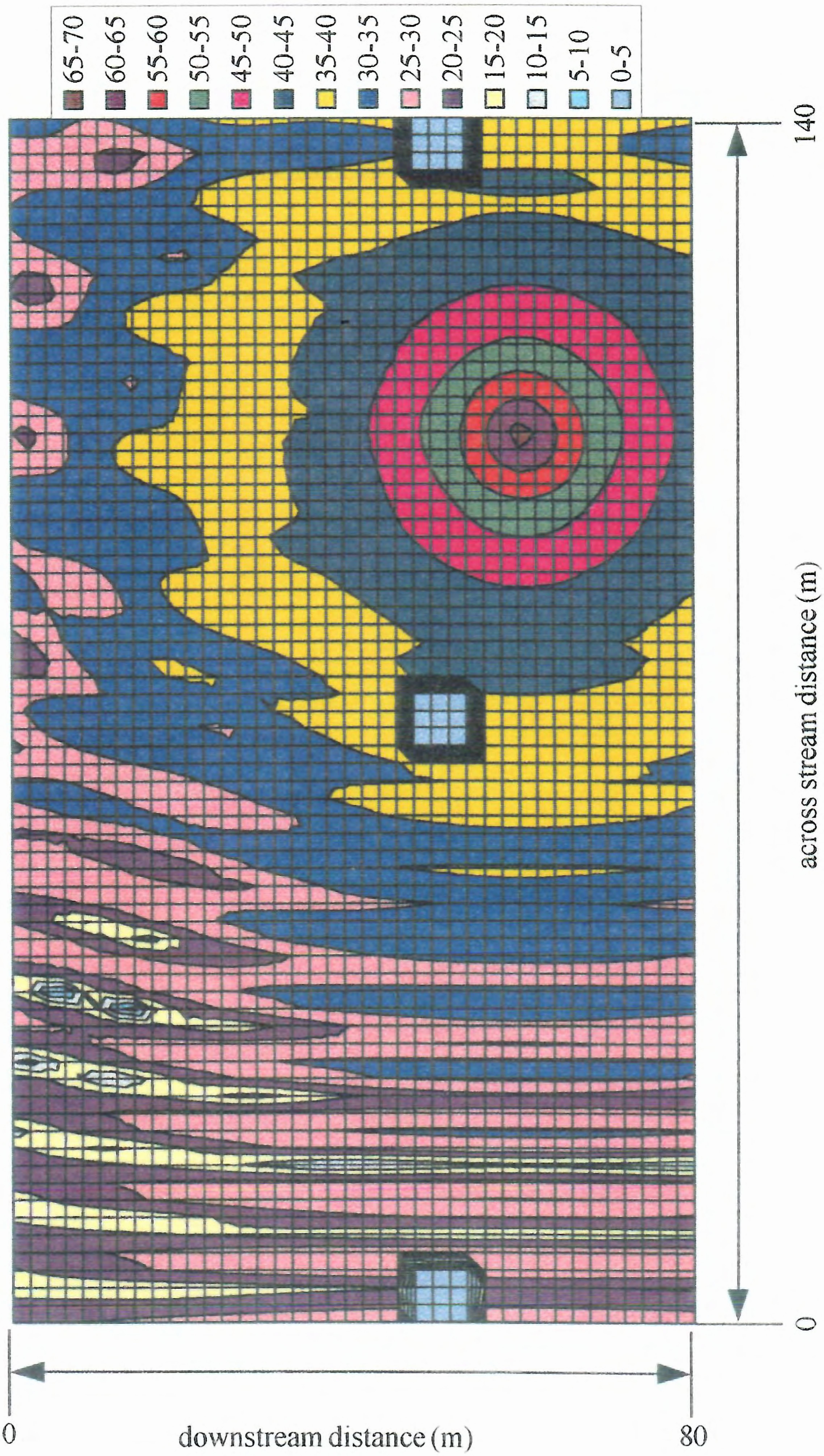


Figure 37

Contour map showing signal to noise levels for a 4 unit SPA located at the bridge piers on the River Rhône (transmitted frequency 100 Hz survey depth 1.5 metres).

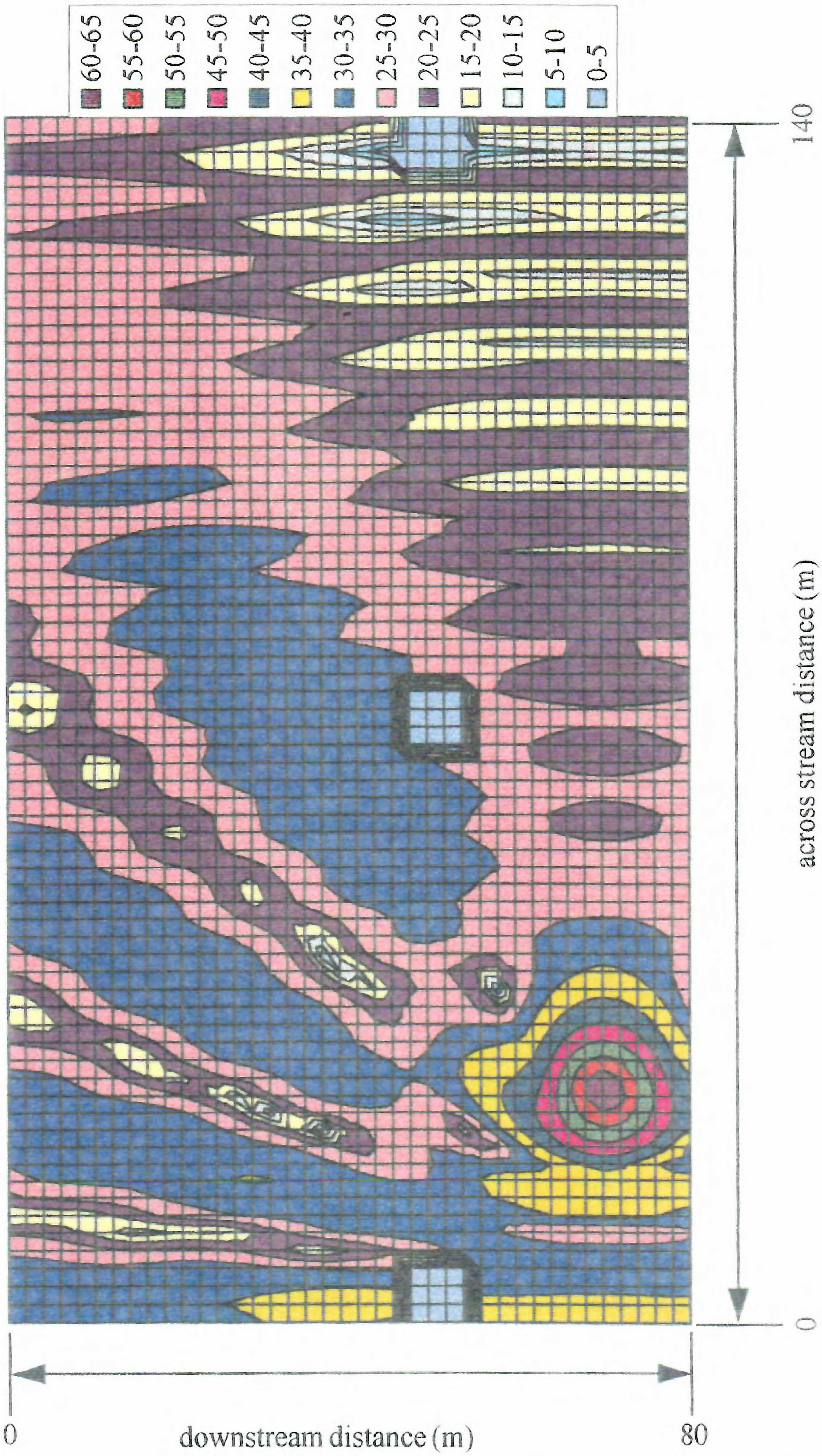


Figure 38

Contour map showing signal to noise levels for a 4 unit SPA located at the bridge piers on the River Rhône (transmitted frequency 100 Hz survey depth 1.5 metres).